THE UNIVERSITY OF ALBERTA

SUCCESSION AND DISTRIBUTION OF OSTRACODA IN HIGHWAY BORROW PIT PONDS OF CENTRAL ALBERTA

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a Thesis entitled Succession and Distribution of Ostracoda in Highway Borrow-Pit Ponds of Central Alberta by Paul Francis Johnston, B.Sc. in partial fulfilment of the requirements for the degree of Master of Science.

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ABSTRACT

Two species of Cypridinae, two species of Cypridopsinae, two species of Cyclocypris, five species of Candona, one species of Ilyocypris and one species of Notodromas are recognized in the borrow-pit pond ostracode community.

A succession of dominant species, Ilyocypris bradyi, Potamocypris smaragdina, Cypridopsis vidua, Cyclocypris serena, Candona spp., Cyclocypris ovum, and Notodromas monacha, is evident in the thirty-two borrow-pit ponds samples seasonally.

Environmental data are used to support the proposed succession as well as to define optimal ranges of the successional species for fourteen selected physico-chemical factors.

Quantitative seasonal and pond distributions of the dominant species are given.

The ostracode succession is considered as a useful tool in making ecological and paleoecological diagnoses in terms of changes in the physico-chemical environment.

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1. INTRODUCTION

The study of Recent fresh-water ostracodes has within the past quarter century become a field of interest for both the zoologist and the micropaleontologist. During this time a more comprehensive knowledge of their biology has been obtained, resulting in the removal of "the stigma of apparent lack of economic or biologic importance" (Hoff, 1942) which had previously curtailed the growth of pertinent literature.

The initial impetus for this renewal of interest came with the suggestion that ostracodes were of some economic importance as potential ecological links between phytoplankton, bacteria, organic detritus and several fresh-water fishes (Rawson, 1930), as well as the discovery that ostracodes were frequently intermediate hosts for the fish-parasitizing Acanthocephala (Hoff, 1942).

With subsequent contributions, it became apparent that the size and the composition of the ostracode assemblage within any one ecosystem could be used as an indicator to determine the physico-chemical condition of that ecosystem.

At about this time, the micropaleontologists who were working with the fresh-water Quaternary faunas became aware of the value of fresh-water ostracode faunas as possible paleoecological indicators. Further, it became apparent that a coordination of the taxonomies evolved by the two groups of workers was a basic necessity to ensure relatively reliable paleoecological interpretations based on the Quaternary assemblages which are extant in Recent fresh-water depositional environments.

The history of the study of Recent fresh-water ostracodes is given by Hoff (1942) for both Europe and North America prior to the date of his publication. Staplin (1963a) continues the résumé of North American studies by adding: "Hoff (1942) contributed an excellent study of Illinois ostracodes and followed it up with short articles

on the species of Mississippi and Louisiana (1943a), and Reelfoot Lake, Tennessee (1943b). Tressler (1941; 1954) issued papers on Puerto Rico, Mexico, and Texas and a checklist of known species of North American fresh-water ostracodes (1947). Several recent papers by Ferguson include a paper on South Carolina species (1958a) and a checklist (1958b)." Other pertinent literature includes Tressler and Smith's (1948) report on the seasonal distribution of ostracodes, as well as Kesling's (1951a; 1951b) two articles dealing with terminology and morphology of ostracode carapaces. Staplin (1956) further demonstrates the use of fresh-water ostracodes as paleoecological indicators, and a short discussion on the ecology of fresh water ostracode assemblages by Benson and MacDonald (1963) again makes manifest their usefulness in paleoecological studies. The need for more emphasis on carapace morphology for taxonomic purposes was underlined by Winkler (1960) in conjunction with his suggestion that "a study of the tolerance of Recent ostracodes to their environments would be a considerable help in the understanding of Pleistocene ostracodes." To this end, Delorme (1964; 1965) published a checklist of Canadian Pleistocene and Recent ostracodes followed by a quantitative summary of some limnological variables and an analyses of their effects upon the resident ostracode assemblages of numerous fresh-water bodies in Saskatchewan.

The present study was developed from a program initiated by Dr. R. Green, Research Council of Alberta, to study the Recent fresh-water ostracode fauna of Alberta and designed to gain insight into the micropaleontology of fresh-water Quaternary deposits of Alberta. The immediate aims of this investigation are to study the sequence of ostracode species inhabiting a series of borrow-pit ponds of different chronological ages through one annual cycle, to assess the physico-chemical condition of the borrow-

pit ponds and ascertain its significance in the successional development of the pond ecosystem, to define and assess the value of an ostracode succession for ecological and paleoecological studies, and to relate the distribution of the species collected to previously reported occurrences in North America.

Field collections were started during the first week in May, 1965, after an extensive reconnaissance of the study area to locate and age date borrow-pit ponds accessible for sampling on a seasonal basis. The May collections were taken from fifty borrow-pit ponds ranging in age from two to twelve years. The ponds selected for preliminary study were along Highways 45 between Bruderheim and Andrew, 18 and 44 between Clyde and Smith, and 43 and 2 between Fox Creek and Guy.

Field work resumed during the first week of July, 1965, with the re-sampling of twenty-two ponds selected from the original fifty and the initial sampling of ten additional ponds of 1947-48, 1952 and 1964 vintages.

The thirty-two borrow-pit ponds sampled in July were chosen for further study. The subsequent and final field collections were made during the second week of October, 1965, and the first week of February, 1966. In February, because of adverse weather conditions, only twenty ponds were sampled. These ponds were selected from the twenty-two originally sampled in May and subsequently in July and October.

II. METHODS AND MATERIALS

1. Field Collections

The sixty borrow-pit ponds chosen for sampling ranged in age from seventeen years to six months and are located in twenty-nine different Townships* of Central Alberta. The locating and age dating of suitable borrow-pit ponds was done during the last week of April, 1965, with the aid of the Department of Highways Annual Reports 1949-50 to 1963-64, and the Construction Branch Highway System Progress Chart, 1963, in conjunction with a reconnaissance by vehicle of the likely localities. Dates of construction and locations of the ponds were later confirmed with the aid of the Highway Contractors' Reports.

An attempt was made to choose a complete chronological spectrum of ponds of similar dimensions within the same physiographic region.

Shore-line surveys of the borrow-pit ponds were carried out using a modified enclosing rectangle method (Welch, 1948, p. 23). Because of the small size and the regularity of shape all distances were paced off parallel to the shore-line. An outline sketch of the pond was immediately entered into the field notebook with the dimensions clearly marked.

Hand-line soundings were plotted on the sketch map as they were taken. The number of soundings made from the rubber boat varied according to the length of the two median transects along which the contours were determined.

Outlines of the original excavations or borrow-pits taken from the Highway Contractors' Reports were traced on cross-section paper and the field contour maps were drawn to scale within these outlines. Contour lines were plotted at one-foot

*Townships - when capitalized will refer to the land area defined by any two successive township and range lines designated by the Alberta Land Surveyors.

or two-foot intervals.

Descriptive terms, symbols, and morphometric calculations used in this manuscript are those suggested by Welch (1948). Pond areas and length of shore-line were determined by direct measurement in the field. Areas enclosed by the contour lines were found using the cross-section paper method (Welch, 1948).

Air and water-surface temperatures were taken with a simple Fisher thermometer graduated to 0.1 degree Centigrade.

Wind intensities were recorded in five main categories (nil, slight, moderate, strong, or gusty) based upon the wind's effect on the rubber boat while sampling.

Water transparency was measured with the standard Secchi disc (Welch, 1948). The limit of visibility was calculated for each set of readings. Apparent colour of the pond waters were noted.

A Beckman Pocket pH Meter was used for hydrogen ion concentration determination in the field. Because of mechanical failure, no pH readings were taken in the field during the July sampling period.

Dissolved oxygen was determined by the Miller method (Miller, 1914) in the field. Water samples for the Miller test were taken with a wide-mouth 200 ml. glass jar one foot beneath the surface. The jar, previously wetted, was lowered mouth down to the one-foot depth, carefully inverted and allowed to fill with water. Before being stoppered and raised to the surface the jar was gently shaken to remove any air bubbles adhering to the inside. After cautiously decanting the excess water off down to a 50 ml. graduation, the sample was tested in the same container. Two determinations were made at each sampling and their average recorded.

Samples of water for chemical analyses were taken using the same procedure as that described for obtaining water samples for the oxygen test. Open-mouth pint sealers were used to collect and transport the water samples to the laboratory.

During the May sampling period bottom samples for both chemical analyses and bottom faunal study were taken with a 1000 ml. stainless steel beaker mounted on a seven-foot aluminum pole. A total of about 600 grams to 1000 grams of wet sediments were collected, comprising a portion taken one yard from the shore along the longest median transect and a portion of equal size taken from the area of maximum depth. Subsequent bottom samples were collected on a similar basis using a six-inch Ekman dredge. The samples were weighed in the field with a 2000 gm. spring balance and transported to the laboratory in 5" x 7" 8-oz. canvas bags.

Plankton samples were taken with a 20-inch diameter conical 200-mesh nylon net during the reconnaissance phase of the project. This net was replaced in the three last sampling periods by a 6-inch diameter "Wisconsin" type plankton net, also of 200-mesh nylon. Two plankton samples were collected at each sampling: one from three total vertical hauls and the other from three two-foot vertical hauls. To each net plankton sample was added 10 ml. of formalin for preservation.

The water, bottom, and plankton samples collected from each pond during any one sampling period were given the same designation. The numbering system used in this study is that used by the Research Council of Alberta.

During the July fieldwork a collection of the prominent aquatic, emergent and shore-line macrophytes was made and transported to the laboratory in polyethylene bags for identification.

All data gathered while collecting were immediately entered on a duplicated form (see Appendix A) to ensure a systematic approach in sampling and to emphasize the comparative nature of the investigation.

2. Laboratory Preparations

The water samples collected for chemical analyses were taken to the Provincial Analyst, Edmonton, at the end of each sampling period.

A 100-gram portion was removed from each bottom sample for faunal study. The remainder of the sample was then weighed and oven-dried at 80°C. for 24 hours. After re-weighing, the dried samples were taken to the Agricultural Soils and Feed Testing Laboratory, University of Alberta, Edmonton, for chemical analyses. The 100-gram samples were placed in polyethylene beakers with a hot tap-water solution of detergent to help break down the clay in preparation for the extraction of the ostracode fauna. Samples with little or no clay-sized particles did not require the two to three grams of detergent normally used.

Vigorous shaking three or four times during the 24-hour soaking period ensured that the wetting solution of detergent was thoroughly mixed with the faunal sample. The sample was then gently washed on a 100-mesh sieve to remove the fine clay and silt-sized particles. Drying of the residue was done on a porcelain saucer in the oven at 80°C.

Dry sieving through a 20-60-80 mesh series divided the residue into four fractions convenient for ostracode picking under a binocular microscope. The fractions were stored in 2-1/2" x 4-1/2" coin envelopes labelled with the appropriate designation and the fraction size.

A preliminary qualitative survey was made to ascertain the number of ostracode species present in each sample by scanning one or two spreads on a five-inch-diameter picking tray from each fraction. Up to 20 specimens of each species were removed from the samples and mounted on micropaleontological slides for study. Simultaneously, a representative number of gastropod, pelecypod, and Chara gyrogonite specimens were picked. Quantitative counts of both the living and dead ostracode assemblages were made on each 100-gram portion taken from the samples selected for detailed study.

The total vertical haul net plankton samples were left undisturbed until the organic material had settled to the bottom of the 200 ml. containers, then the supernatant water was carefully decanted off. Using an eye-dropper, the residue was transferred to a petri dish for scanning. A qualitative collection of the ostracode fauna present in each sample was removed and mounted in the same manner as the dried specimens. Quantitative counts of the ostracode plankton were made on both net plankton samples taken at each sampling period.

3. Photomicrography

A Zeiss photomicroscope equipped with an automatic camera was made available for use during this study by the Research Council of Alberta, Edmonton. The photomicroscope with both epi- and trans- illuminating facilities was ideal for photographing the semi-transparent to translucent valves of the ostracodes. Gonad traces and muscle scars were readily visible by use of a judicious combination of the two light sources (see Plate III, Figure 1).

Lens settings on the microscope were; projective X3.2, and optovar X2.0. The objective was a Leitz-Photar epiplan (f = 25 mm; M = 1:2.5).

Adox KB14 film was used and the final prints were finished commercially.

Specimens to be photographed were cleared in xylene after having been treated with 70 and 95 per cent alcohol. The specimens were left about ten minutes in each solution. Curtin micropaleontological slides were used for mounting when epi-illumination was used and concave one-inch by three-inch zoological glass slides were used when trans-illumination was desirable. Canada balsam was used as a mounting medium in the concave slides.

The plates were photographed and printed by Mr. M. Kiss of the Zoology Department.

III. PREVIOUS WORK

There has been no previously published work dealing primarily with the ostracode faua of Alberta. The borrow-pit ponds sampled during the course of this study, similarly, have never been studied as a distinct ecological category prior to this investigation.

Seven borrow-pit ponds were sampled during the second week in July, 1964, by Dr. R. Green and the writer. Temperature, pH, dimensions, and brief descriptions of bottom sediments, obvious macroflora and macrofauna, as well as the locations were recorded at that time. Two of the seven ponds were located within the Central district as defined in this manuscript. The remaining five are either to the west of or within the Western district. Collections of both the benthic and plankton ostracode fauna indicated that there was sufficient diversity to warrant further study.

The checklist of Canadian Pleistocene and Recent fresh-water ostracodes published by Delorme (1964) included the Alberta species that were previously identified by Dr. R. Green.

IV. PHYSIOGRAPHY OF THE STUDY AREA

1. Geographic Location and General Description

The study area lies between parallels of latitude 53°30' and 55°30' North and between meridians of longitude 118° and 112° West. In terms of Alberta land surveying, it lies within townships 53 to 75, ranges 13 to 27 and 1 to 27, west of the fourth and fifth meridian, respectively. The total area is approximately 33,550 square miles.

Most of the 60 borrow-pit ponds selected for sampling are situated along Provincial Highways 43, 44, and 45. Hence, sampling is confined to three districts within the study area totalling about 1040 square miles. For the sake of reference in this manuscript, these districts are designated as Western, Central and Eastern (Figure 1).

In the Western district, lying within townships 61 to 75, ranges 17 to 21, west of the fifth meridian, a total of 18 ponds from nine different Townships were sampled. Twenty-nine ponds were sampled in the Central district which lies within townships 59 to 69, ranges 25 to 27 and 1, west of the fourth and fifth meridians. The remaining 13 borrow-pit ponds are located in the Eastern district within townships 56 to 57, ranges 16 to 20, west of the fourth meridian and are situated in nine different Townships.

Figure 2 shows the locations and the sample numbers of the borrow-pit ponds studied in this investigation. More precise pond locations and the elevations are given in Appendix B.

The study area is part of the plains region of Alberta, an undulating plateau varying in elevation from about 800 feet in the north to roughly 3500 feet in the southwest (Moss, 1955). The elevation of the study area ranges from about 1900

Figure 1. Extent of the study area and sampling districts.

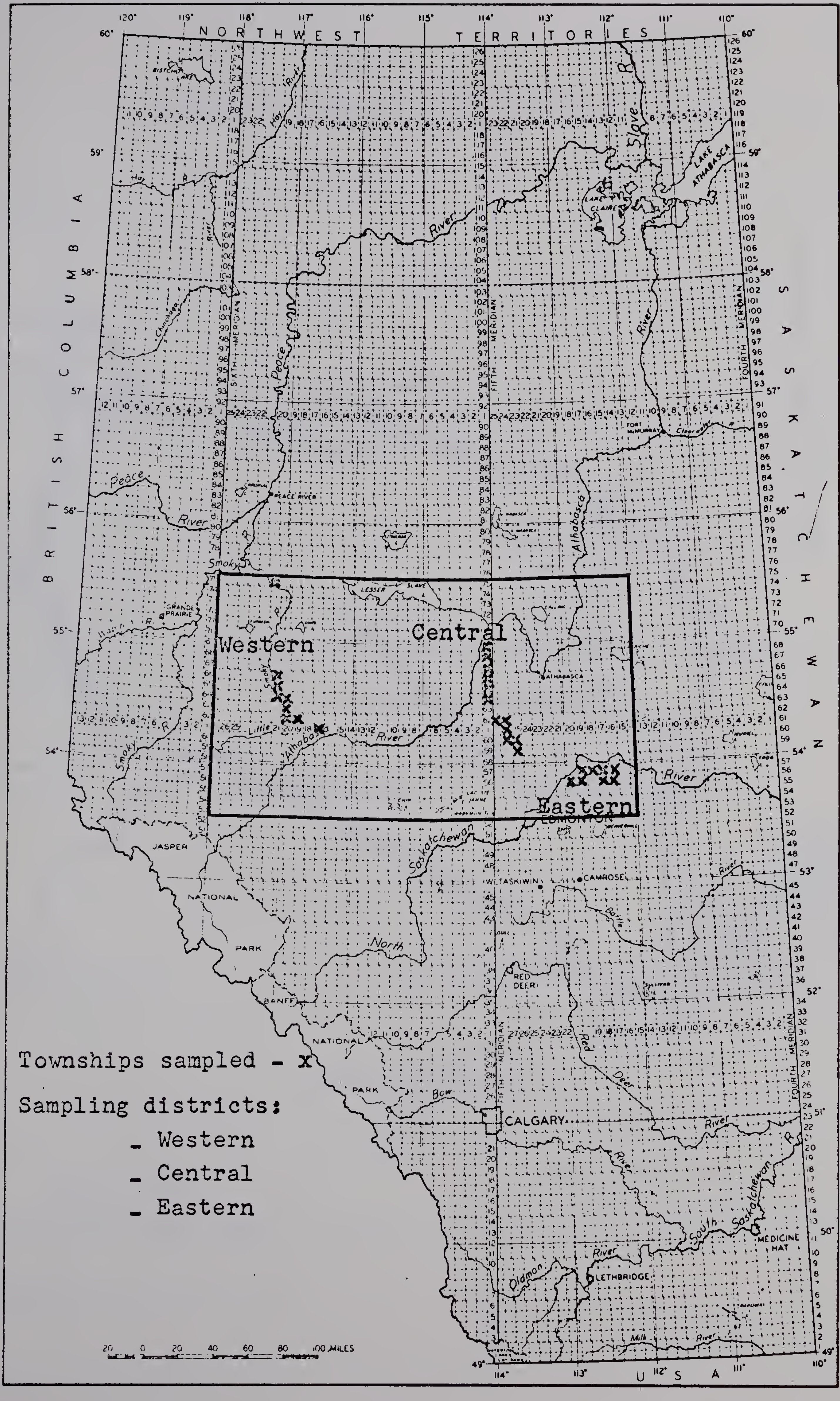
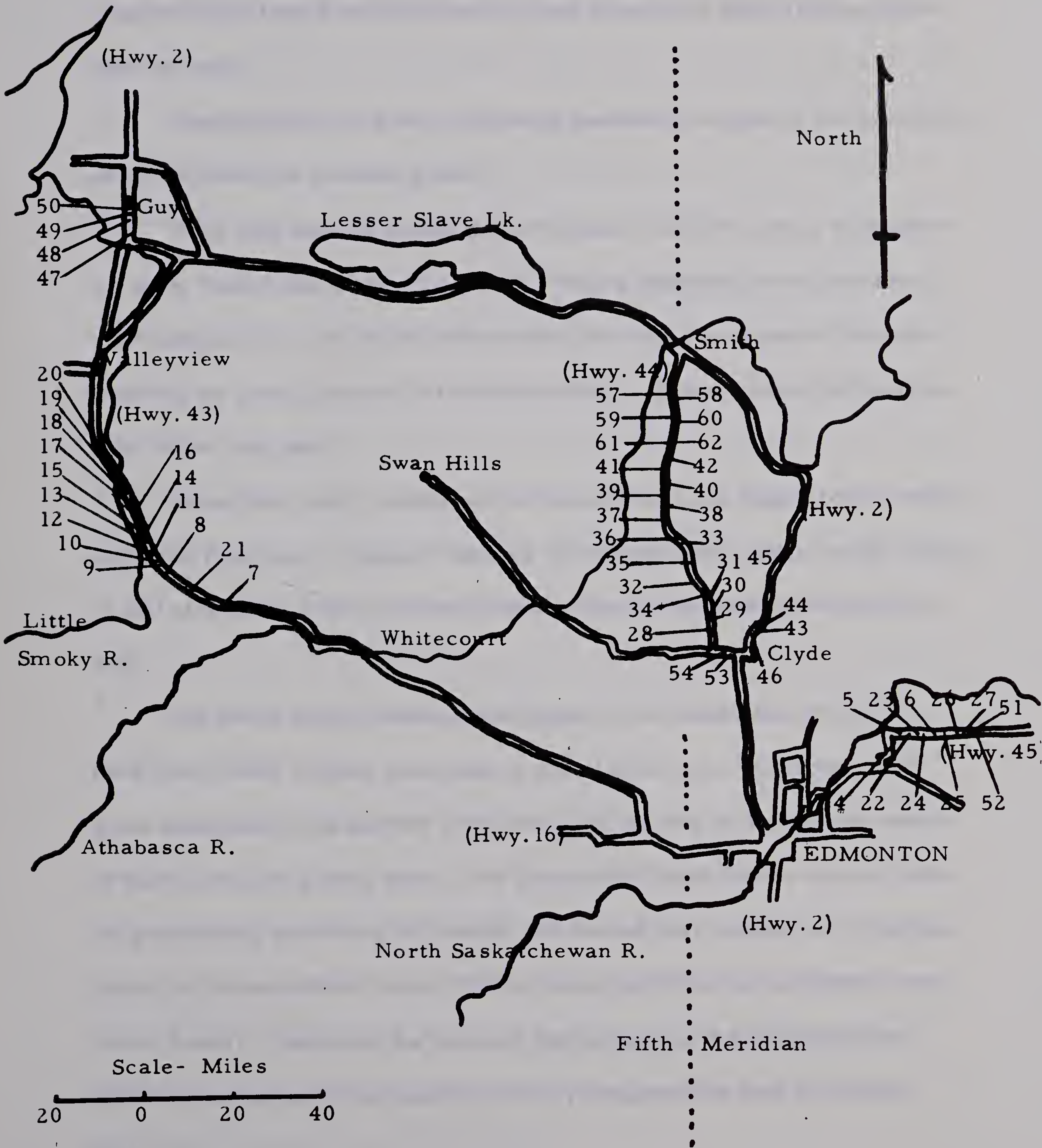

NORTHWEST TERRITORIES
BRITISH COLUMBIA
SASKATCHEWAN
U S A
LAKE ATHABASCA
LAKE CLAIRE
Slave R.
Peace River
Hay River
Athabasca River
Smoky R.
Little Smoky
Saskatchewan River
North Saskatchewan
Battle R.
Red Deer River
Bow River
Oldman River
South Saskatchewan
Milk River
LESSER SLAVE
GRANDE PRAIRIE
PEACE RIVER
FORT McMURRAY
ATHABASCA
EDMONTON
WETASKIWIN
CAMROSE
RED DEER
CALGARY
LETHBRIDGE
MEDICINE HAT
JASPER NATIONAL PARK
BANFF NATIONAL PARK
SIXTH MERIDIAN
FIFTH MERIDIAN
FOURTH MERIDIAN
Western
Central
Eastern
Townships sampled - x
Sampling districts:
- Western
- Central
- Eastern
20 0 20 40 60 80 100 MILES

Figure 2. Sample numbers* and borrow-pit pond locations.

*for Pond numbers see Table II.

Locations of sampled borrow-pit ponds



Sample numbers: 4 to 62.

feet in the northwest to 2700 feet above mean sea level in the southwest. There is a regional slope toward the east where the mean elevation is about 2100 feet above mean sea level.

Topographically, the most conspicuous feature of the region is the Swan Hills, which rise above the surrounding plain.

Three main drainage systems dissect the area. The Little Smoky River adjacent to the Western district flows northward. Flowing diagonally to the northeast is the Athabasca River. The North Saskatchewan River flows in an easterly direction, dissecting the plains just north of the Eastern district. Figure 2 shows the three main rivers of the study area.

Lesser Slave Lake, situated north of Swan Hills, is the largest body of water within the study area. However, there are innumerable smaller lakes, ponds, sloughs as well as countless minor rivers and streams, reflecting the moderate relief of the area.

The area is largely forest-covered except in the Eastern district, which is more open, having a higher percentage of natural grass cover. Agriculture is of prime importance in the east half of the study area resulting in a subsequent removal of much of the native forest cover. The Eastern and Central districts are well suited for grain farming and raising of livestock with limited dairy production. In contrast, within the Western district there is limited farming activities and considerable emphasis on forestry. Because of the nature of their economies, the communities are small, and consequently the population density throughout the area is relatively low.

2. Geology

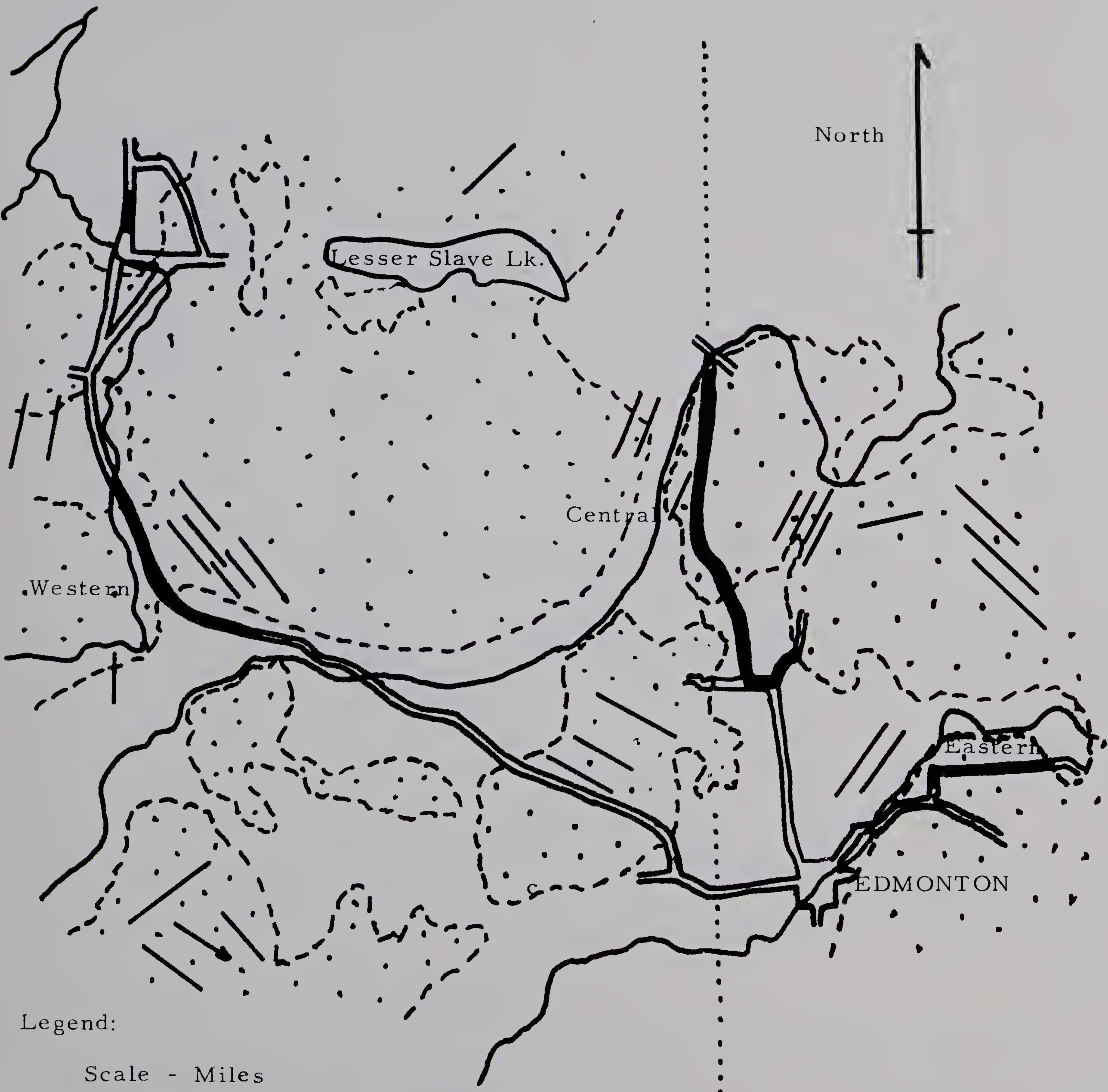
Detailed mapping of the surficial Quaternary deposits of the study area is incomplete despite the fact that sporadic studies within or adjacent to the area have taken place over the past 75 years (Barton et al., 1964). A brief review of the Quaternary studies of Western Canada was published by the Alberta Society of Petroleum Geologists, Calgary, Alberta, in December, 1964.

In general, the study area was completely covered by the southwest advance of the continental Laurentide ice sheet of Wisconsinan age. There is no evidence of glaciation in the area during pre-Wisconsinan times. As a result of the Laurentide glaciation, the preglacial topography was almost completely mantled with a varying thickness of Quaternary sediments. These deposits are categorized on the basis of the presence or absence of stratification. The unstratified or poorly stratified deposits of tills, drift, and outwash gravels were laid down in direct association with the mobile ice sheet. The well-stratified category, characteristically glacio-lacustrine and glacial fluvial, was deposited in indirect association with the retreating or melting ice sheet.

According to Gravenor and Bayrock (1961) the Laurentide glacial advance occurred more than 31,000 years ago. Some glacial landforms within the study area give testimony for the final deglaciation by ice stagnation and subsequent melting. Deglaciation is thought to have occurred in the area about 11,000 years ago. Figure 3 shows the distribution of the two categories of Quaternary deposits, and positions and orientations of the major landforms which indicate the direction of pre-stagnation glacial flow within the area.

Figure 3. Quaternary deposits and major glacial landforms.

Quaternary Deposits



Legend:

Scale - Miles

20 0 20 40

Stratified drift (fluvial-lacustrine) _

Till (plus ice-contact stratified drift _ and loess)

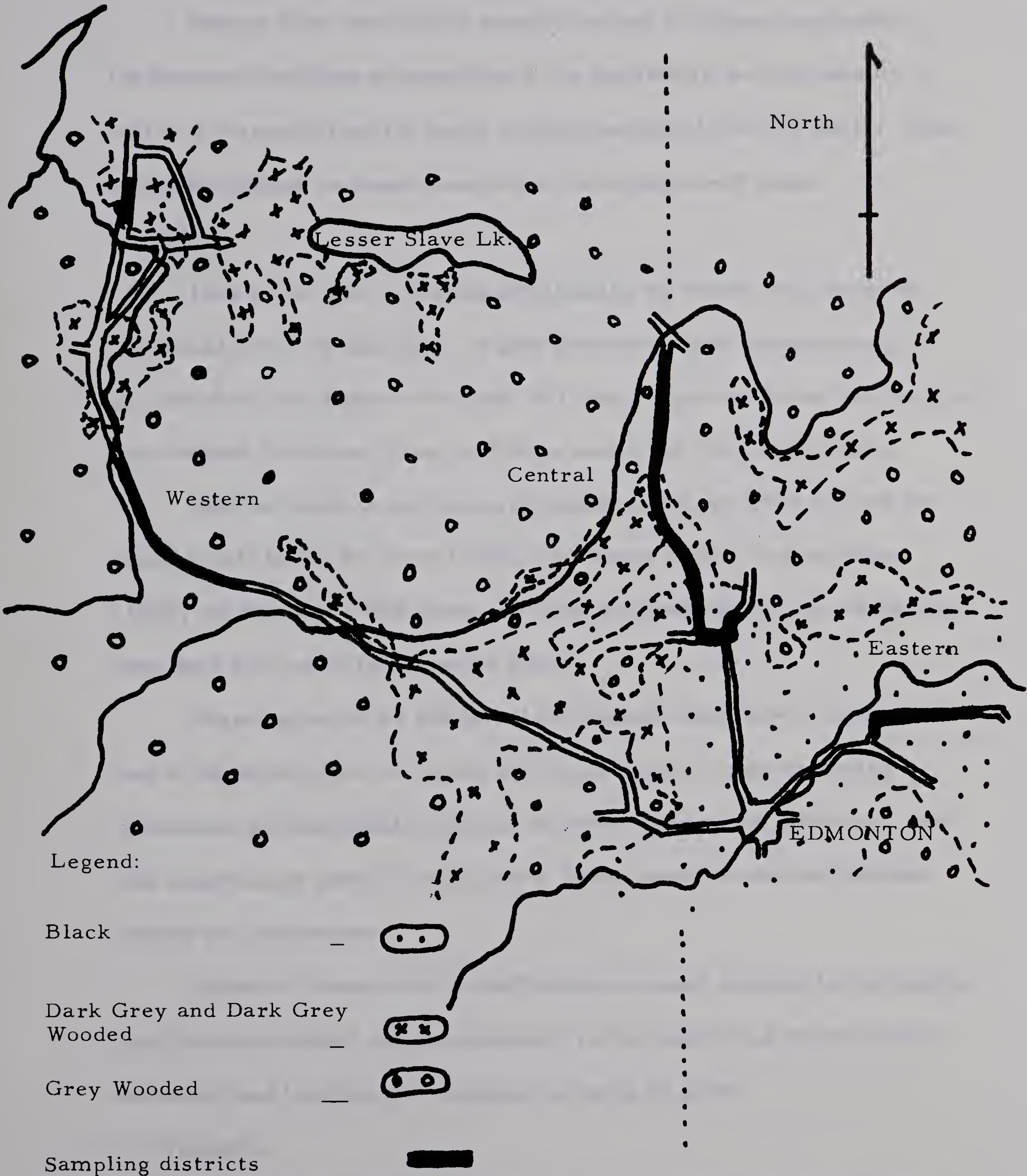
Sampling districts _

Ice flow indicators _

Modified after: Barton et al., 1964.

Figure 4. Major Soil Zones within the study area.

Soil Zones



Modified after: Alberta Soil Survey map.

Because of the nature of the materials required in highway construction, the borrow-pits originate as excavations in the stratified silt and clay deposits, as well as in the unstratified tills having a high percentage of fine silty matrix. These excavations become permanent reservoirs for the surface run-off waters.

3. Soils

Three of the major Soil Zones established by the Alberta Soils Survey are represented within the study area. In gross quantitative terms, approximately 10 per cent of the total area is in the Black Soil Zone, 10 per cent in the Dark Grey and Grey Wooded Transitional Zones, and 80 per cent in the Grey Wooded Zone.

Detailed reports on soil surveys of separate map sheets within the area are available only for the Ste. Anne (1930), High Prairie (1952), Grande Prairie (1956), and Edmonton (1962) sheets. Of these published reports, only the Edmonton sheet deals with the soils of a sampled district.

The soil survey of the east half of the Edmonton sheet (83-H) indicates that most of the borrow-pits of the Eastern district are located in areas covered by chernozemic soils developed on alluvial lacustrine materials and glacial till. Notable exceptions are ponds 51 and 52 east of Andrew where till-derived solodized solonetz soils predominate.

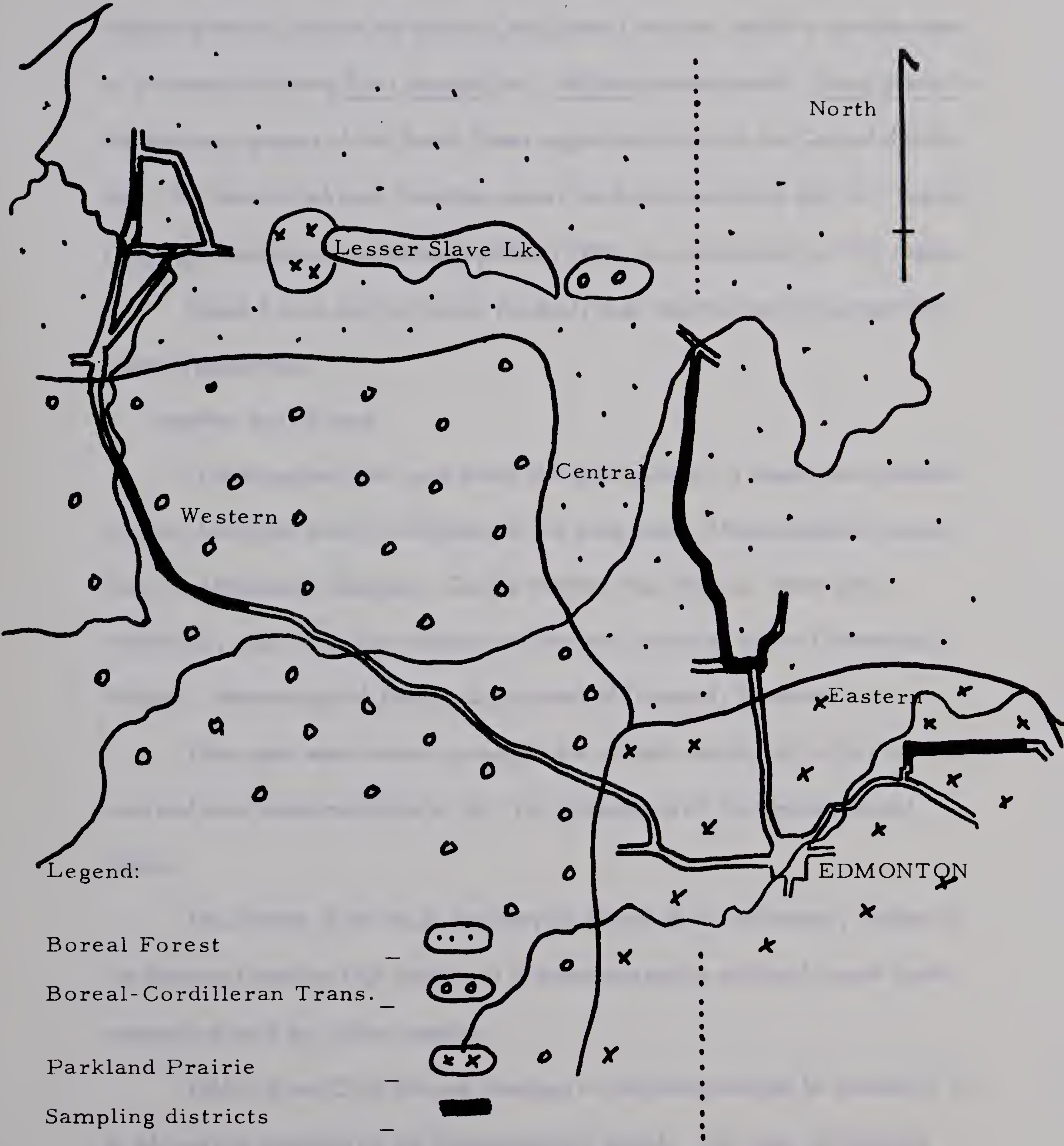
Appendix C shows the soil classification and parent materials for the sampled localities where official data are available. For the Central and Western districts borrow-pit pond localities only the major soil zones are given.

4. Vegetation

Each of the three sampling districts lies within a different phytogeographic

Figure 5. Phytogeographic regions of the study area.

Phytogeographic Regions



Modified after: Moss, 1955.

region or plant life zone as summarized and illustrated by Moss (1955). The Western district is within the Boreal-Cordilleran Transition which is characterized by a community where Pinus contorta var. latifolia predominated. Picea glauca is the dominant species of the Boreal Forest region within which the Central district lies. The Boreal-Parkland Transition covers the Eastern sampling district. Popular (Populus) Association, as defined by Moss (1955), is characteristic of this region.

Figure 5 is an outline map of the study area showing the phytogeographic regions represented.

5. Weather and Climate

Climatological data upon which this brief summary is based were recorded in seven localities within or adjacent to the study area. Meteorological records from the Athabasca, Edmonton, Grande Prairie, High Prairie, Slave Lake, Vermillion, and Whitecourt weather stations were compiled by the Climatology Division, Meteorological Branch, Department of Transport, Edmonton.

These data were chosen to register the climatic variability within the study area and were made available by Mr. Van Volkenberg of the Meteorological Branch.

The climate of the study area may be described as continental, typical of the Western Canadian high plains. It is characterized by relatively warm humid summer and cold dry winter weather.

Table I gives 25 to 30-year averages or adjusted averages for periods of 10 to 24 years as compiled by the Meteorological Branch. The mean temperature based upon the annual averages recorded by all stations is 34.5°F. Athabasca

Table 1. Meteorological statistics for the study area.

ANNUAL AND MONTHLY MEANS OF TEMPERATURE AND PRECIPITATION

Locality	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Parameter*
Athabasca	.00	.00	.02	.43	1.67	2.77	3.00	2.50	1.37	.36	.10	.03	12.25	Rainfall
	11.7	9.7	8.3	3.9	1.3	0.0	0.0	0.0	0.2	4.8	9.3	11.0	60.2	Snowfall
	1.17	.97	.85	.82	1.80	2.77	3.00	2.50	1.39	.84	1.03	1.13	18.27	Tot. Prec.
	1.5	6.2	17.9	36.6	48.8	55.3	60.5	57.9	49.4	38.8	21.4	7.6	33.5	M. Temp.
Edmonton	.01	.01	.05	.50	1.71	3.15	3.34	2.55	1.26	.49	.14	.05	13.26	Rainfall
	9.4	7.6	7.8	6.0	1.2	0.0	0.0	0.0	0.9	4.1	7.4	9.4	53.8	Snowfall
	.95	.77	.83	1.10	1.83	3.15	3.34	2.55	1.35	.90	.88	.99	13.64	Tot. Prec.
	6.6	11.2	22.1	39.5	52.1	57.8	63.1	60.0	51.5	41.2	24.5	13.3	36.9	M. Temp.
Grande Prairie	.01	.03	.06	.03	1.47	2.31	2.43	1.79	1.50	.56	.37	.09	10.92	Rainfall
	13.6	13.4	10.5	5.7	.2	T	T	0.4	1.6	3.3	12.3	13.6	74.6	Snowfall
	1.37	1.37	1.11	.60	1.49	2.31	2.43	1.83	1.66	.89	1.60	1.45	18.38	Tot. Prec.
	3.1	8.4	19.5	37.0	50.0	56.3	60.3	58.6	49.9	38.1	23.3	9.5	34.5	M. Temp.
High Prairie	.06	.03	.07	.49	1.48	2.73	2.91	2.30	1.39	.67	.27	.11	12.53	Rainfall
	9.1	8.4	7.3	4.4	0.3	0.0	0.0	0.4	0.7	5.6	8.7	9.8	54.7	Snowfall
	.97	.87	.82	.93	1.51	2.73	2.91	2.34	1.46	1.23	1.14	1.09	18.0	Tot. Prec.
	2.5	8.5	20.7	37.4	50.2	56.4	61.0	57.9	49.6	39.3	21.7	9.3	34.5	M. Temp.
Slave Lake	.05	T	.07	.40	1.65	2.60	3.02	2.55	1.65	.58	.14	.01	12.72	Rainfall
	9.0	9.1	7.6	4.5	0.6	0.0	0.0	0.0	0.5	5.7	9.1	9.9	56.0	Snowfall
	.95	.91	.83	.85	1.71	2.60	3.02	2.55	1.70	1.15	1.05	1.00	18.32	Tot. Prec.
	1.7	7.3	19.8	36.9	49.1	55.3	60.6	57.6	49.1	38.5	21.7	7.9	33.8	M. Temp.
Vermilion	.01	T	.03	.36	1.09	2.50	2.58	3.04	1.39	.39	.12	.02	11.53	Rainfall
	7.0	5.4	6.7	5.0	0.8	0.0	0.0	0.0	1.4	3.5	5.2	7.3	42.3	Snowfall
	.71	.54	.70	.86	1.17	2.50	2.58	3.04	1.53	.74	.64	.75	15.76	Tot. Prec.
	1.4	5.8	18.2	37.4	50.8	56.1	61.9	58.7	50.3	39.7	21.5	8.2	34.2	M. Temp.

ANNUAL AND MONTHLY MEANS OF TEMPERATURE AND PRECIPITATION

Locality	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Parameter*
Whitecourt	.01	.02	.03	.46	1.76	2.87	3.86	3.33	1.26	.43	.16	.09	14.28	Rainfall
	11.1	9.7	7.8	7.4	0.9	0.1	0.0	0.0	0.5	6.4	6.9	9.5	60.3	Snowfall
	1.12	.99	.81	1.20	1.85	2.88	3.86	3.33	1.31	1.07	.85	1.04	20.31	Tot. Prec.
	5.0	10.5	21.8	36.9	48.3	54.4	54.7	56.5	48.5	38.0	21.7	8.0	34.2	M. Temp.

*Rainfall, Snowfall, and Total Precipitation are given in inches.
Mean Temperature is given in ^{o}Fahrenheit.

These data are from: CDS #5-65 and CDS #9-64.

reports an annual mean of 33.5°F which is the low mean for the area. The high mean of 36.9°F. was recorded at the Edmonton Municipal Airport. A minimum mean of 1.4°F. is reported from Vermillion for the month of January. The maximum monthly mean within the area is 63.1°F. recorded in Edmonton for July.

Variations in monthly and annual mean totals of precipitation are less pronounced in a north-south direction than east-west. Athabasca, High Prairie, Slave Lake, Grande Prairie, and Edmonton all report mean yearly totals within 0.30 inches of the area mean total of 18.24 inches. However, between Vermillion in the east with 15.76 inches and Whitecourt in the west with 20.31 inches there is a significant increase in the mean annual total precipitation. The monthly maximum and minimum within the area were recorded during July at Whitecourt with 3.86 inches and during February at Vermillion with 0.54 inches.

Based upon the 1964 records from Edmonton and Grande Prairie, there were between 4485 and 4515 total hours of daylight for the year within the area. Edmonton has recorded a mean yearly total of 2203 hours of sunshine while Grande Prairie reports a mean yearly total of 2109 hours.

V. PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE BORROW-PIT PONDS

1. Morphometry

Table II is a list of morphometric data for the thirty-two ponds selected for study. Ponds 8 and 28 are illustrated in Figure 6. Figure 7 is bathymetric maps for six of these ponds chosen to illustrate the extremes of variation as well as form.

Mean water depths range from 1.1 feet (ponds 19 and 27) to 14.0 feet (32) with a mean of 4.3 feet.

The areas range from 0.09 acres (3) to 3.16 acres (18) with a mean of 1.15 acres.

Shore development and shoreline-area ratios are all relatively low. The mean shore development is 1.22; the range is from 1.12 (9 and 31) to 1.57 (18). Length of shoreline divided by the area ranges from .013 (17 and 22) to .077 (3) with a mean of .024.

Only one out of the thirty-two ponds is not rectangular in shape (Figure 7B). The regular shoreline and the uniform bottom profiles are a result of the mode of origin.

2. Nature of the bottoms

Natural infilling of the borrow-pits alters the bottom profiles at a relatively rapid rate. Most of the infilling may be attributed to two interrelated processes, shoreline erosion and sedimentation.

Extensive evidence of shoreline erosion is found on the pit slopes in the form of rain-gashes, soil-creeps, and slump-blocks. While these erosional forms are

Table II. Some morphometric data for the thirty-two study ponds.

Sample Number	Pond Number	Area (acres) A	Maximum depth(ft.) Z m	Mean depth(ft.) Z	Z/Zm	Zm/ A	Shore-line(ft.) S	S/A /Ft.	Shore development	Date or excavation 19-	Sampling Districts
(57)	1	0.22	7.5	3.8	.51	.077	444	.047	1.29	47-48	Central
(58)	2	0.40	3.5	1.4	.50	.026	534	.031	1.14	47-48	
(60)	3	0.09*	5.5	3.5	.63	.087	306*	.077*	1.36	47-48	
(62)	4	2.11	5.5	2.7	.49	.018	1302	.014	1.24	47-48	
(53)	5	0.57	6.5	4.8	.73*	.041	660	.027	1.18	52	
(54)	6	0.53	8.0	4.8	.60	.053	648	.028	1.21	52	
(17)	7	0.27	3.8	1.6	.42	.035	588	.050	1.53	53	Western
(20)	8	1.04	4.3	2.5	.58	.020	852	.019	1.13	53	
(12)	9	1.00	8.5	3.8	.38	.041	846	.019	1.12*	54	
(16)	10	0.53	3.8	1.9	.50	.025	714	.031	1.33	54	
(8)	11	0.79	5.5	2.9	.52	.030	884	.026	1.35	55	
(10)	12	0.41	3.2	1.9	.59	.024	546	.031	1.16	55	
(47)	13	0.47	10.5	5.2	.49	.042	1056	.016	1.18	56	
(48)	14	0.73	16.2	9.1	.56	.091	714	.022	1.13	56	
(28)	15	1.55	3.5	1.4	.40	.013*	1050	.016	1.14	57	Central
(30)	16	1.75	5.8	2.5	.43	.021	1146	.015	1.18	57	
(31)	17	2.80	11.2	5.6	.50	.032	1614	.013*	1.31	57	
(32)	18	3.16*	3.5	1.2	.34*	.094	2060*	.015	1.57*	58	
(33)	19	0.79	2.5*	1.1*	.44	.014	840	.024	1.28	58	
(38)	20	0.80	13.0	6.8	.52	.070	804	.023	1.22	59	
(39)	21	1.77	11.5	5.5	.47	.042	1110	.015	1.13	59	
(45)	23	1.60	3.5	1.8	.52	.013*	1060	.015	1.13	60	
(46)	22	2.13	14.6	9.1	.62	.044	1260	.013*	1.16	60	
(40)	24	1.00	11.0	7.0	.63	.053	918	.021	1.24	61	
(42)	25	1.61	10.0	5.2	.52	.038	1140	.016	1.22	61	
(5)	26	0.95	7.5	4.0	.53	.037	828	.020	1.15	62	Eastern
(22)	27	0.80	3.2	1.1*	.34*	.017	762	.022	1.15	62	
(6)	28	1.12	7.5	3.7	.49	.034	918	.019	1.17	62	
(61)	29	0.63	4.5	2.9	.64	.027	702	.026	1.20	62	
(25)	30	0.85	5.1	3.2	.62	.026	804	.022	1.17	63	
(51)	31	1.18	20.0*	11.4	.57	.088	920	.018	1.12*	64	
(52)	32	0.93	20.0*	14.0	.70	.095*	840	.021	1.18	64	
	Means	1.15	7.9	4.3	.52	.043	870	.024	1.22		

*Extremes

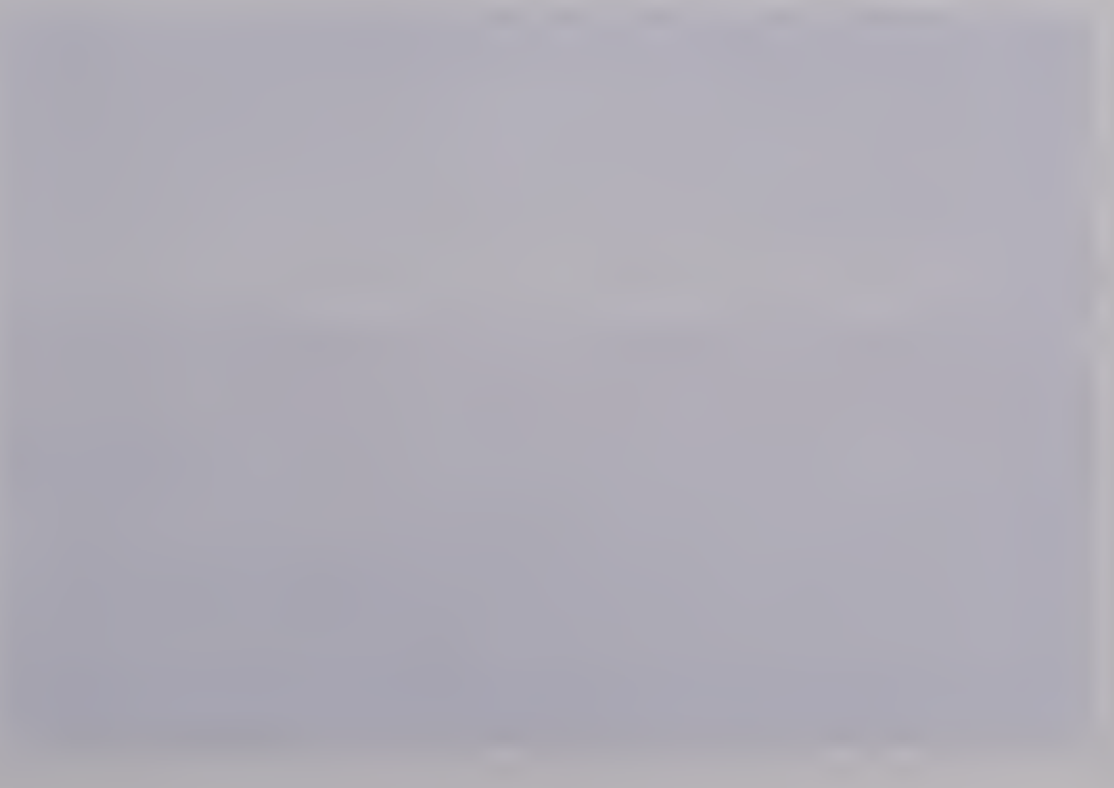


Figure 6. Habitats: Ponds 8 and 28.

Pond 8 - July 1965

(SW 1/4 Sec. 20 Tp. 66 Rg. 21 W5M)

Algal bloom in a pond constructed in 1953.

Pond 28 - October 1965

(NE 1/4 Sec. 36 Tp. 56 Rg. 19 W4M)

Sampling a pond constructed in 1962.

Figure 7. Bathymetric maps of ponds 31, 18, 19, 32, 3 and 17.

(A) Pond 31 - Minimum shoreline development. July, 1965.

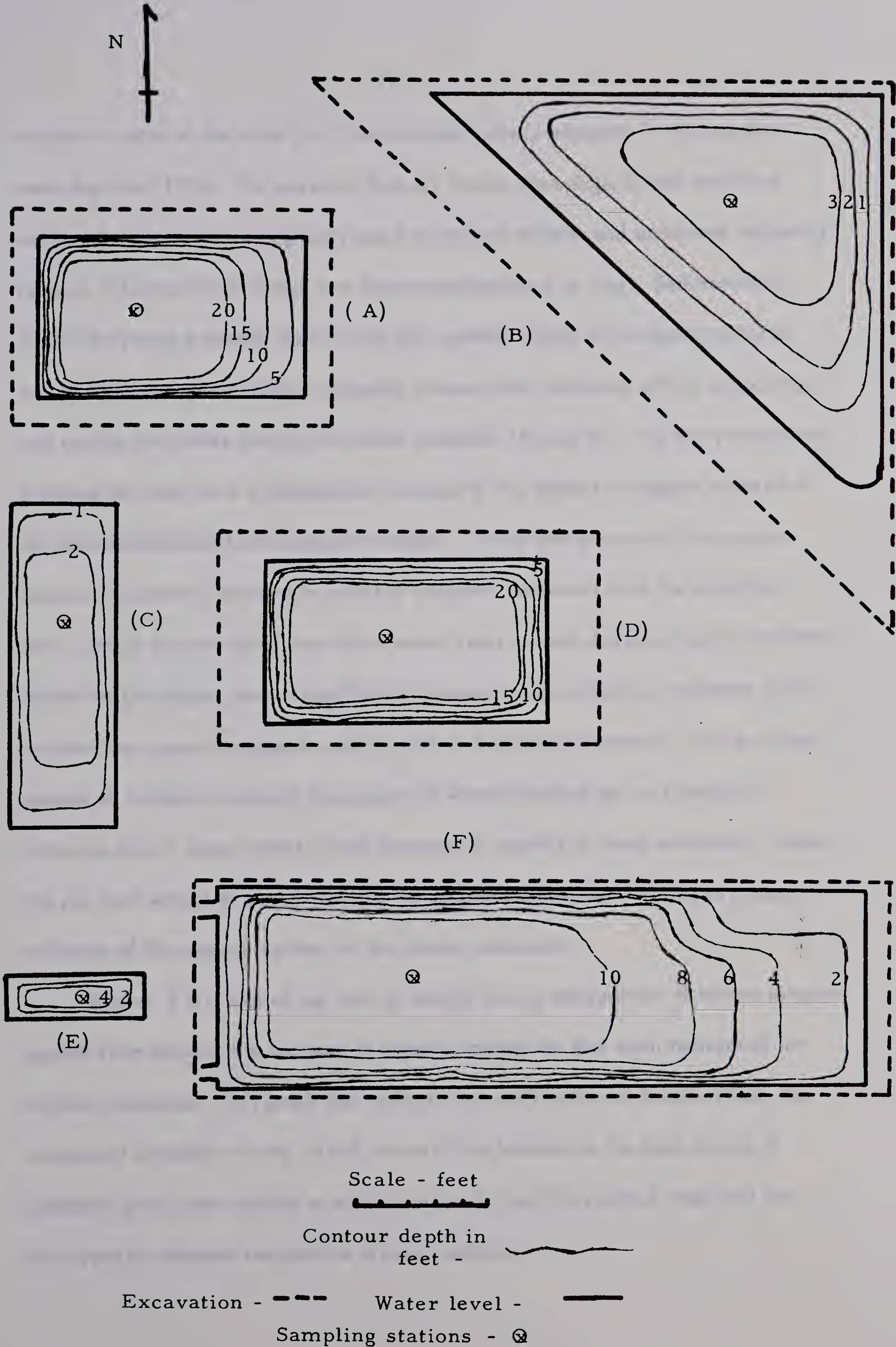
(B) Pond 18 - Maximum shoreline development and maximum area. May, 1965.

(C) Pond 19 - Minimum mean water depth. May, 1965.

(D) Pond 32 - Maximum mean water depth. July, 1965.

(E) Pond 3 - Minimum area and maximum shoreline/area ratio. May, 1965.

(F) Pond 17 - Minimum shoreline/area ratio. May, 1965.


N
(A)
20
15
10
5
(B)
3 2 1
(C)
1
2
(D)
5
20
15 10
(E)
4 2
(F)
10
8
6
4
2
Scale - feet
Contour depth in feet -
Excavation -
Water level -
Sampling stations -

evident in some of the older pits, they are particularly apparent in the pits that were dug after 1958. The materials that are moved downslope by the combined action of water, frost, and gravity are a mixture of surface and subsurface sediments ranging in texture from almost pure coarse-grained sand to clay. Sedimentation within the ponds proceeds rapidly with this constant supply of inorganic material and the bottom becomes fairly uniformly covered with sediments with a composition and texture not unlike that of the source materials (Figure 8). The thirty-two ponds selected for study show a gradational increase in the amount of organic material in the bottom sediments from youngest to oldest. In the younger ponds this organic material is primarily brought in with the inorganic sediments from the shoreline area. Ponds that are older than six or seven years, where shoreline erosion has stabilized the pit slopes, show a significant increase in autochthonous sediments which increase the organic-inorganic weight ratio of the bottom materials. For any given texture of inorganic material the amount of water absorbed per unit weight of bottom sediment varies directly with the organic content of these sediments. Hence, the per cent weight of water loss from the bottom samples may be used as a rough indicator of the organic content of the bottom sediments.

Figure 9 is a plot of per cent of weight loss by dehydration of bottom samples against time showing the increase in organic content for four main textures of inorganic sediments. This graph also reflects the stabilization of the shoreline, the subsequent alteration in the initial nature of the bottoms as the main source of sediments shifts from outside to within the ponds, and the relative rates that the four types of substrate accumulate organic material.

Figure 8. Texture, relative organic content and mean per cent water weight of the bottom sediments.

A. Change in texture and inorganic content with pond age.

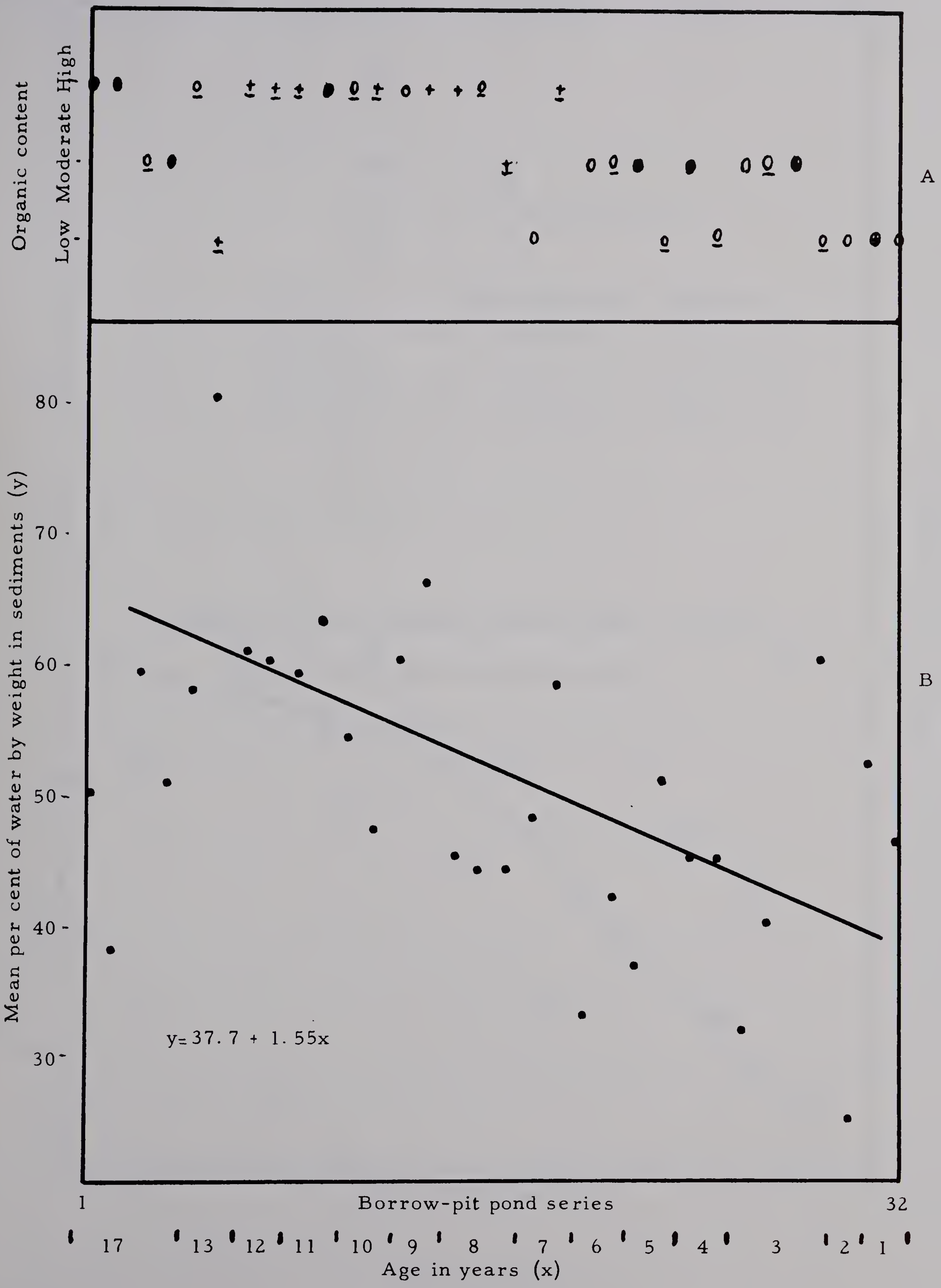
Key to texture Sandy - 0

Silty - + $\underline{\circ}$ Sandy-clay

$\pm$

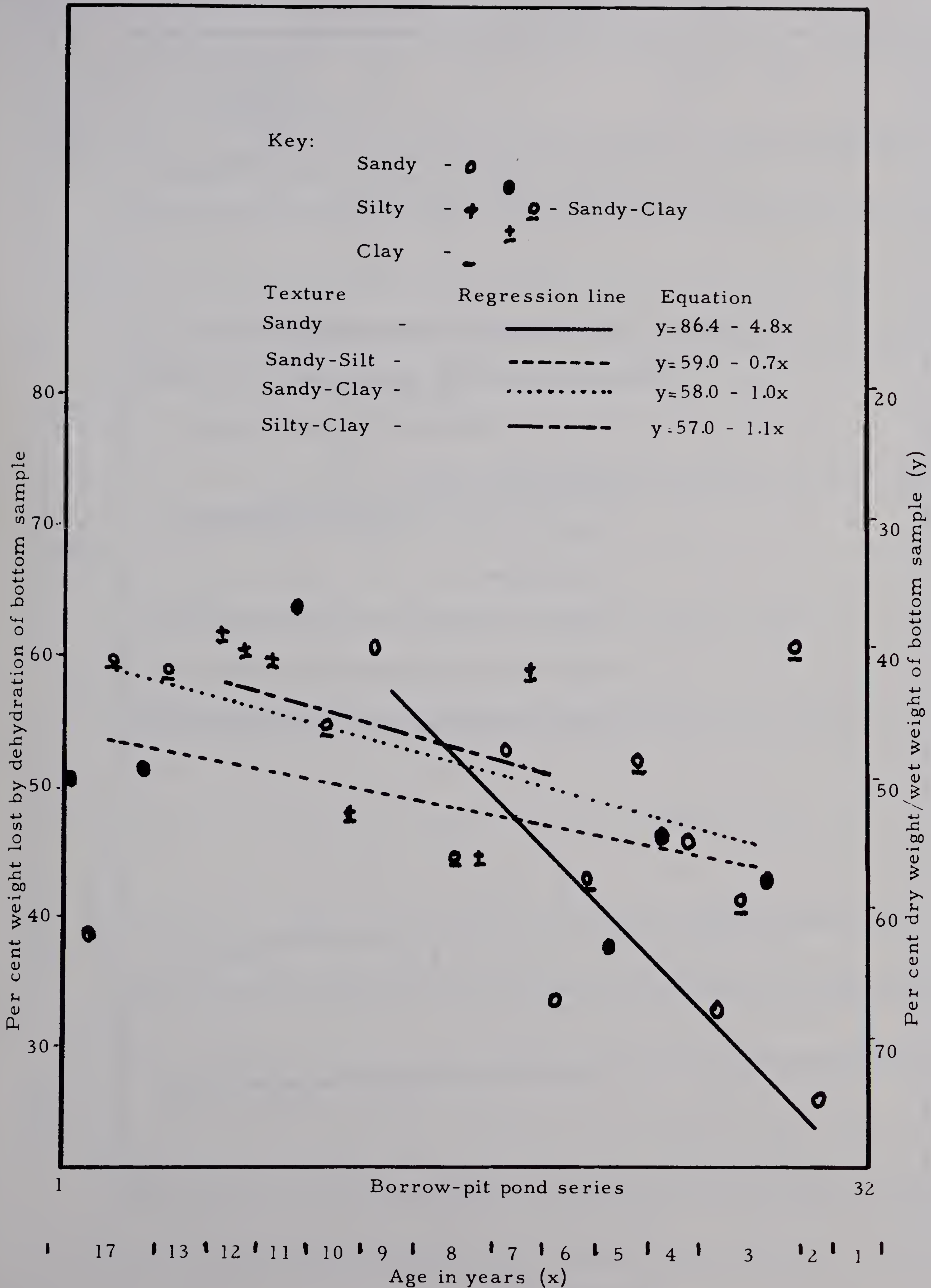
Clay - $-$

B. Change in mean per cent of water by weight with pond age.



Organic content
Low Moderate High
A
Mean per cent of water by weight in sediments (y)
80
70
60
50
40
30
B
y= 37. 7 + 1. 55x
1
Borrow-pit pond series
32
17
13
12
11
10
9
8
7
6
5
4
3
2
1
Age in years (x)

Figure 9. Relative changes in organic content for four different textures of inorganic sediments through time.



Key:
Sandy - o
Silty - +
Clay - _
Sandy-Clay
Texture
Regression line
Equation
Sandy -
y= 86.4 - 4.8x
Sandy-Silt -
y= 59.0 - 0.7x
Sandy-Clay -
y= 58.0 - 1.0x
Silty-Clay -
y= 57.0 - 1.1x
80
70
60
50
40
30
20
30
40
50
60
70
Per cent weight lost by dehydration of bottom sample
Per cent dry weight/wet weight of bottom sample (y)
1
Borrow-pit pond series
32
17
13
12
11
10
9
8
7
6
5
4
3
2
1
Age in years (x)

Figure 10. Chemical analysis of bottom sediments; means for samples taken during May and July from thirty-two ponds.

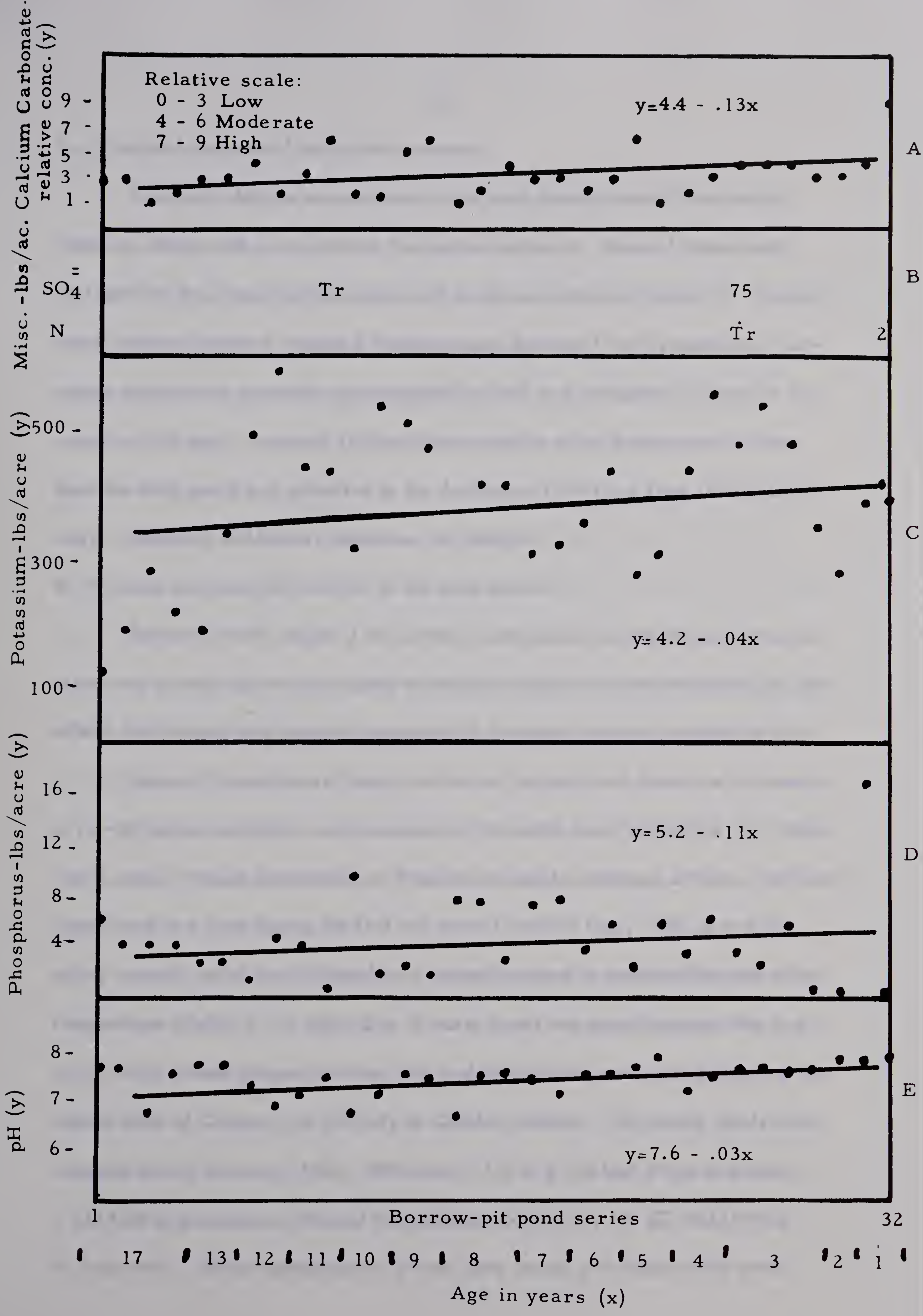
A. Change in relative calcium carbonate concentration with pond age.

B. Changes in sulfate and nitrogen concentrations with pond age.

C. Change in potassium concentration with pond age.

D. Change in phosphorus concentration with pond age.

E. Change in hydrogen ion concentration with pond age.



Calcium Carbonate-relative conc. (y)
Relative scale:
0 - 3 Low
4 - 6 Moderate
7 - 9 High
y=4.4 - .13x
A
Misc. -lbs/ac.
SO4=
Tr
75
B
N
Tr
2
Potassium-lbs/acre (y)
500
300
100
y=4.2 - .04x
C
Phosphorus-lbs/acre (y)
16
12
8
4
y=5.2 - .11x
D
pH (y)
8
7
6
y=7.6 - .03x
E
1
Borrow-pit pond series
32
17
13
12
11
10
9
8
7
6
5
4
3
2
1
Age in years (x)

3. Chemical analyses of the bottom sediments

As organic detritus accumulates on the pond bottom through time certain chemical changes take place within the bottom sediments. Some of these chemical data for the chronological spectrum of ponds are plotted in Figure 10. General trends that are apparent include a slight average decrease in pH, phosphorus, potassium and calcium carbonate concentration as well as a noticeable increase in pH variation with age. Appendix D gives the test results of the bottom samples taken from the study ponds and submitted to the Agricultural Soils and Feed Testing Laboratory, University of Alberta, Edmonton, for analysis.

4. Physical and chemical analysis of the pond waters

Surface run-off, which is the primary water source for the borrow-pit ponds, is not only a major factor with regard to shoreline erosion and sedimentation but also affects the physical and chemical properties of the water reservoirs within the pits.

Seasonal fluctuations of precipitation and temperatures determine the amount of run-off waters available, and consequently the water level within the pit. Water loss is mainly through evaporation as there are no regular drainage outlets. The water levels were at a peak during the first and second week of May, 1965, due to the spring run-off, which was initiated by a marked increase in precipitation and rising temperatures (Table I). A slight drop in water levels was noted between May and July, while marked drops of between four and eight inches were recorded during the second week of October, for the July to October interval. The lowest levels were recorded during February, 1966. With from 1 1/2 to 2 1/2 feet of ice and about 1 1/2 feet of snow cover, three of the shallower ponds (15, 19, 27) had little or no free water. Direct comparison of winter water levels with those of the other

three seasons was not attempted.

To illustrate the age changes in the physico-chemical conditions of the waters the mean values of July and October are used. These data are plotted for the thirty-two ponds ranked according to age (Figures 11, 12 and 13).

Appendix E is a synopsis of the data gathered in the field as well as the results from the water analysis carried out by the Provincial Analyst.

The mean limit of visibility (Welch, 1948) in relation to the maximum depths is shown in Figure 11A.

The total solids less the ignition loss (Figure 11B) also shows an overall decrease with aging. The peak at pond 6 is due to a high concentration of bicarbonates (Figure 12B); those peaks at ponds 13, 14, and 28 may be attributed to the sulfate content (Figure 13B); and the peak at pond 23 results from the combination of a relatively high chloride content and a moderately high concentration of bicarbonates (Figures 13A and 12B).

The ignition loss increases slightly with age (Figure 11C), while chlorides and sulfates concentrations show an overall tendency to decrease with increase in pond age (Figures 13A and 13B).

Alkalinity (Figure 12B) increases and hardness (Figure 13C) reflects the trend of decrease in dissolved inorganic constituents. The alkalinity for most ponds is mainly due to the presence of the bicarbonates of calcium, magnesium, and sodium. Hardness may be attributed to the bicarbonates, sulfates, and chlorides of these same elements. Clearly, the ponds with the highest concentration of sulfates have the highest hardness rating (Figures 13B and 13C).

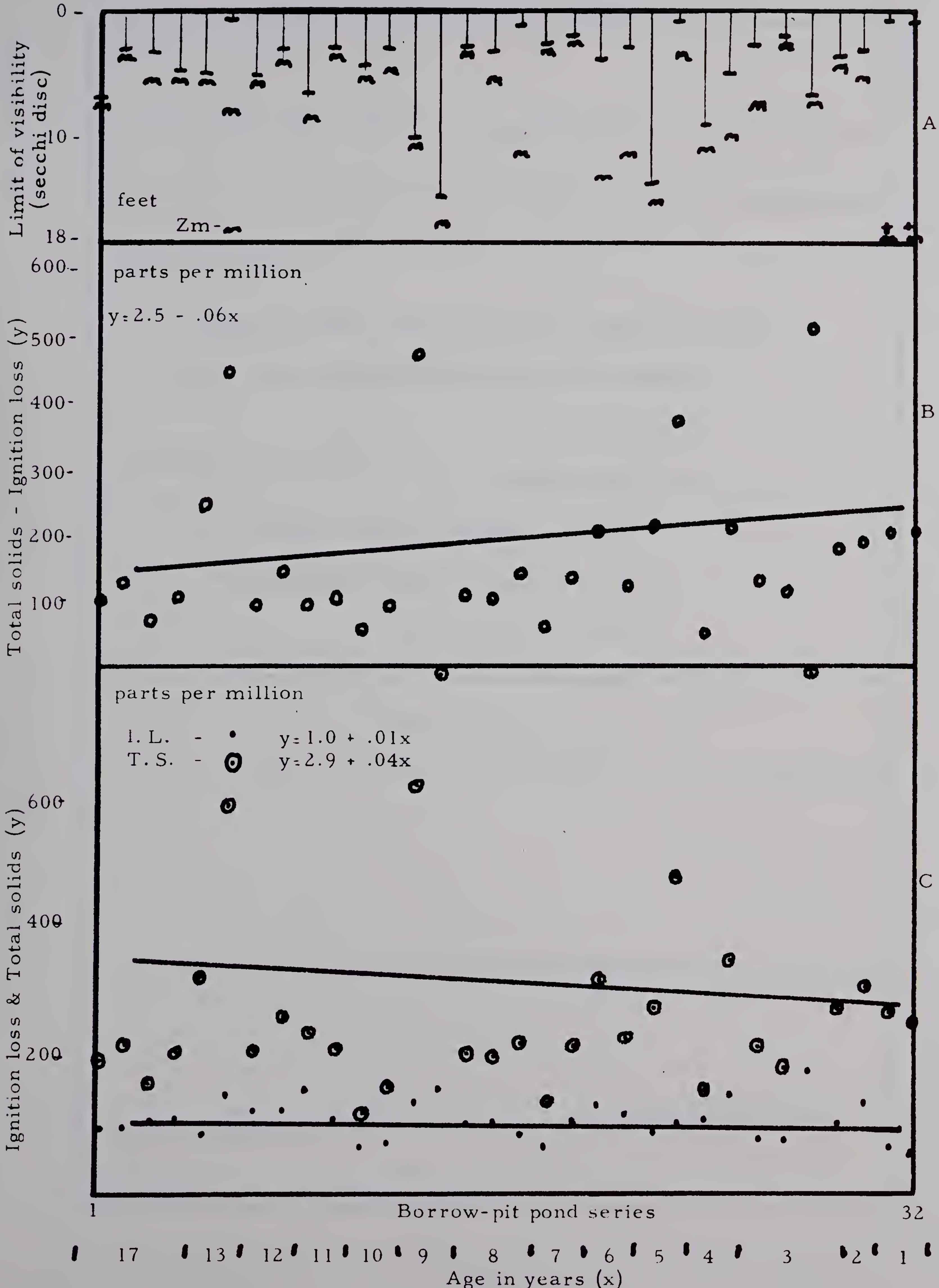
Figure 11. Changes in mean limit of visibility, total solids, ignition loss and total inorganic solids of the waters with pond age.

A. Limit of visibility: maximum depth (~) is indicated for each of the thirty-two ponds

B. Total inorganic solids (Total solids-Ignition loss).

C. Ignition loss and total solids.

Ponds referred to in the text: 5, 6, 13, 14, 23 and 28.



Limit of visibility (secchi disc)
0
10
18
feet
Zm
A
600
500
400
300
200
100
parts per million
y=2.5 - .06x
Total solids - Ignition loss (y)
B
parts per million
I. L. - • y=1.0 + .01x
T. S. - ◎ y=2.9 + .04x
600
400
200
Ignition loss & Total solids (y)
C
1
Borrow-pit pond series
32
17
13
12
11
10
9
8
7
6
5
4
3
2
1
Age in years (x)

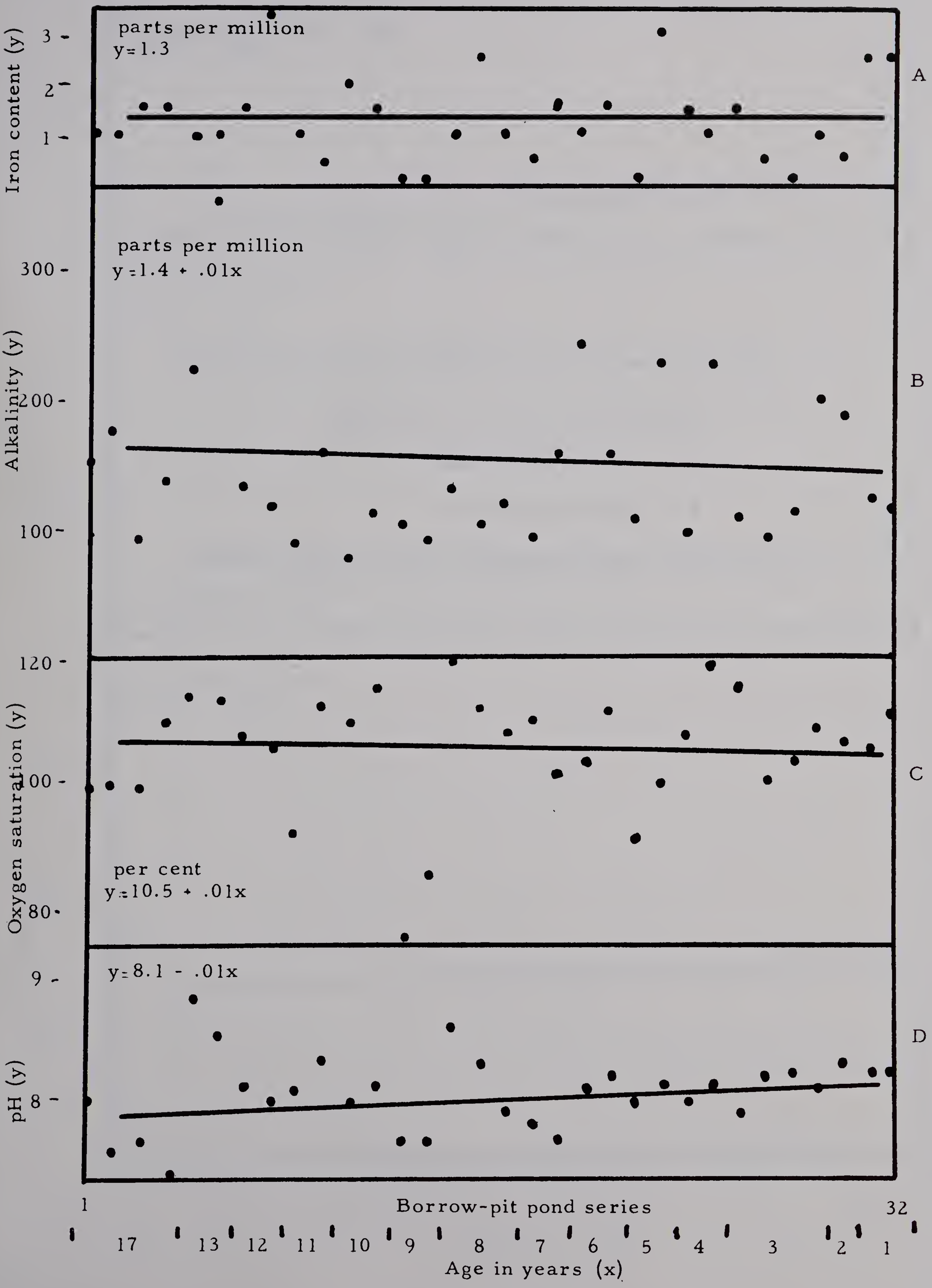
Figure 12. Changes in mean iron content, alkalinity, oxygen saturation and hydrogen ion concentration of the water with pond age.

A. Iron content.

B. Alkalinity expressed in parts per million of the specific alkalinity in terms of calcium carbonate (Theroux et al., 1943).

C. Oxygen saturation.

D. Hydrogen ion concentration.



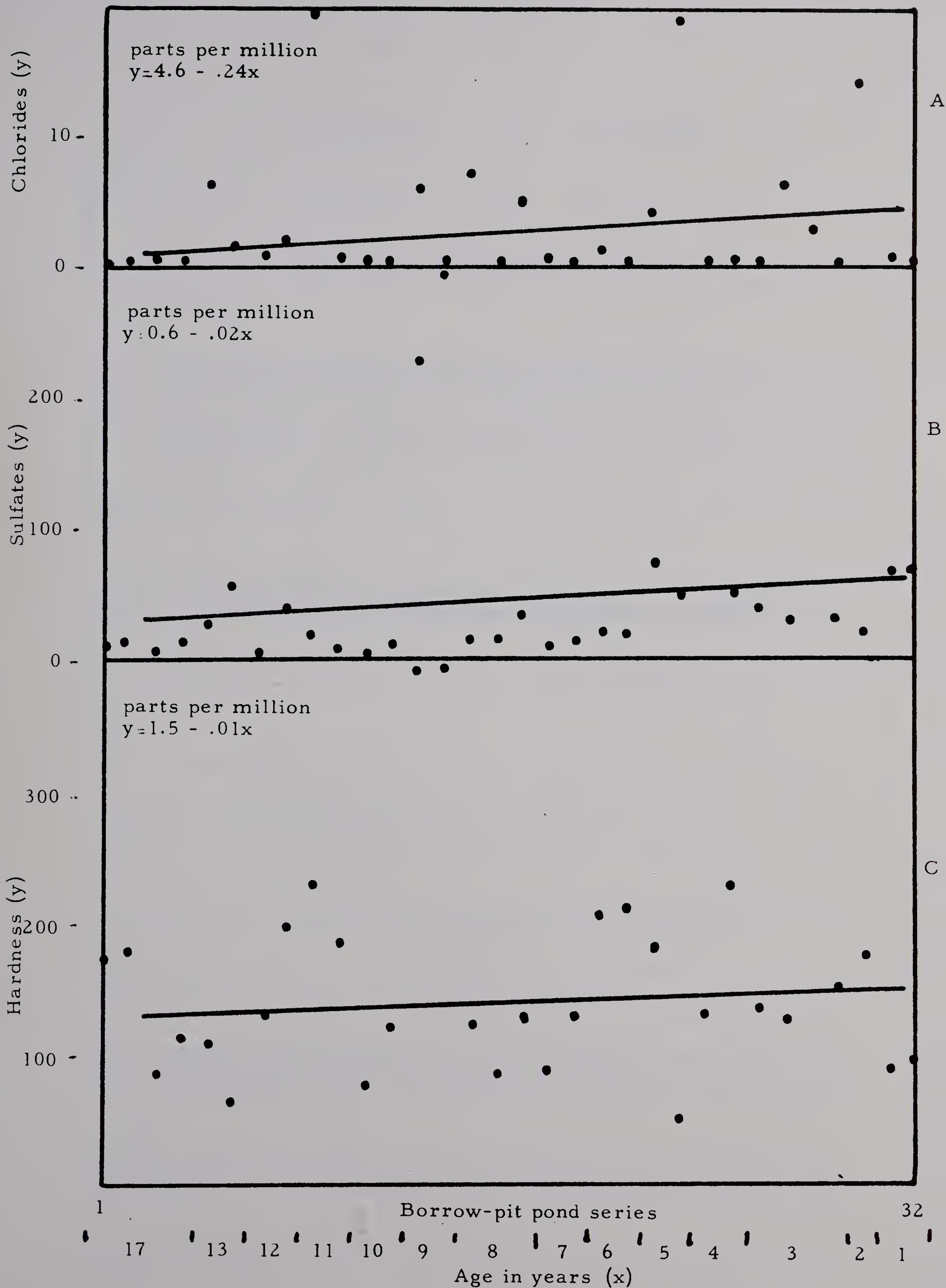
Iron content (y)
parts per million
y=1.3
A
Alkalinity (y)
parts per million
y=1.4 + .01x
B
Oxygen saturation (y)
per cent
y=10.5 + .01x
C
pH (y)
y=8.1 - .01x
D
Borrow-pit pond series
1
32
17 13 12 11 10 9 8 7 6 5 4 3 2 1
Age in years (x)

Figure 13. Changes in mean chloride and sulfate concentrations and hardness of the water with pond age.

A. Chloride concentration.

B. Sulfate concentration.

C. Hardness expressed in terms of calcium carbonate.



Chloridеs (y)
parts per million
y=4.6 - .24x
10
0
A
Sulfates (y)
parts per million
y=0.6 - .02x
200
100
0
B
Hardness (y)
parts per million
y=1.5 - .01x
300
200
100
C
1
Borrow-pit pond series
32
17
13
12
11
10
9
8
7
6
5
4
3
2
1
Age in years (x)

Table III. A record of the oxygen saturation for thirty-two borrow-pit ponds.

Pond Number	Elev. feet	May Temp. °C	May Oxygen cc/l	May Oxygen % sat.	July Temp. °C	July Oxygen cc/l	July Oxygen % sat.	October Temp. °C	October Oxygen cc/l	October Oxygen % sat.	February Temp. °C	February Oxygen cc/l	February Oxygen % sat.
1	2200	--	--	--	19	6.9	112	4	7.5	88	--	--	--
2	2200	--	--	--	18.5	6.5	107	3	8.3	95	--	--	--
3	2200	--	--	--	18	6.1	99	3	7.8	99	--	--	--
4	2100	--	--	--	20	6.9	115	7	8.7	105	--	--	--
5	2200	--	--	--	20.5	7.3	124	6	8.4	105	--	--	--
6	2200	--	--	--	18.5	7.2	118	7	8.5	107	--	--	--
*7	2600	14	7.7	116	23	6.2	111	9	7.8	106	-0.5	5.3	55
*8	2300	13	11.6	126	25	5.9	109	8	8.0	104	-1.0	3.8	41
*9	2600	14	9.2	126	19	5.8	100	8	6.5	86	0.0	5.2	59
*10	2500	14	8.9	133	22	6.3	111	8	8.3	112	0.0	5.5	60
*11	2700	14	9.2	130	19.5	6.7	113	9	7.8	106	-0.5	3.5	38
*12	2600	14	9.9	120	18	7.4	122	9	8.0	108	-1.0	2.8	32
13	1900	15	3.5	54	21.5	5.8	100	--	--	--	--	--	--
14	1900	12	5.1	73	21.5	5.8	100	--	--	--	--	--	--
*15	2200	13.5	7.2	107	20	8.4	142	6	7.8	98	-0.5	--	--
*16	2100	15	8.8	130	20	7.8	130	7	7.4	94	-1.0	5.4	57
17	2100	11	8.2	114	--	--	--	7	8.0	101	--	--	--
*18	2100	13	7.8	114	19	8.4	135	7	7.9	86	-1.0	--	--
*19	2000	14	9.3	135	20	7.0	119	6	6.4	82	-1.0	--	--
*20	2100	12.5	7.8	114	20	6.5	110	8	7.6	99	0.5	6.8	71
*21	2100	12.5	6.4	92	19.5	7.8	127	7	7.9	97	-1.0	6.4	67
*22	2100	13.5	7.8	114	20.5	4.5	76	6	8.4	105	-0.5	7.0	76
*23	2100	13.5	8.4	121	18	8.2	132	4	5.8	68	-1.0	4.8	51
*24	2200	12.5	8.8	126	20	6.5	109	6	8.5	106	-0.5	7.8	82
*25	2200	13	6.9	101	19.5	7.8	131	7	8.4	107	-0.5	7.2	76
*26	2000	13	4.8	67	21	7.2	123	8	8.8	108	-0.5	--	--
*27	2000	9	9.8	122	21.5	6.0	103	5.5	8.2	99	-0.5	--	--
*28	2000	13	9.0	129	21.5	5.8	103	7	8.4	105	-0.5	--	--
29	2100	--	--	--	18	7.3	118	7	8.0	101	--	--	--
*30	2100	12	9.1	129	22	6.1	108	6	8.7	106	-0.5	--	--
31	2100	--	--	--	22	6.5	113	5	8.3	99	--	--	--
32	2100	--	--	--	21.5	6.8	117	5	8.7	105	--	--	--

*Included in the seasonal study.

Per cent oxygen saturation is given on Figure 12C. Table III is a record of the elevations, seasonal water temperatures, seasonal concentrations of oxygen in cubic centimeters per liter, and the resulting per cent saturations for the thirty-two ponds. A slight increase in mean oxygen saturation characterizes the ponds from youngest to oldest.

Figure 12D illustrates the change in the hydrogen ion concentration for the thirty-two ponds ranked according to age. The resulting curve sums up the trends in an overall sequential comparison of the physico-chemical nature of the ponds' waters. Accumulation of the organic autochthonous materials is registered by a decrease in the pH. Differential rates of accumulation possibly due to the general edaphic conditions of the pond localities results in a wider range in pH values between ponds of similar age in the pre-1958 ponds. Humic materials dissolved and suspended in waters give a pond a characteristic clear yellow-brown look. The incidence of pond waters with this colouring is higher among the older ponds. Humics would naturally have a depressing effect on the pH values.

Seasonal ranges in some selected physico-chemical parameters for the 20 ponds sampled during May, July, October and February, are plotted in Figures 14 and 15. Ranges in alkalinity, hardness, pH, and oxygen saturation, shown in Figure 14A to D, all increase with increasing pond age. This seasonal variation within the ponds is not so apparent for those parameters plotted in Figure 15A to C. The limit of visibility shows maximum variability in both the youngest and the oldest ponds of the series and the overall trend indicated by the regression line is one of a decrease with increasing pond age. Seasonal ranges for both total solids and ignition loss show no definite trend but again the regression lines indicate an

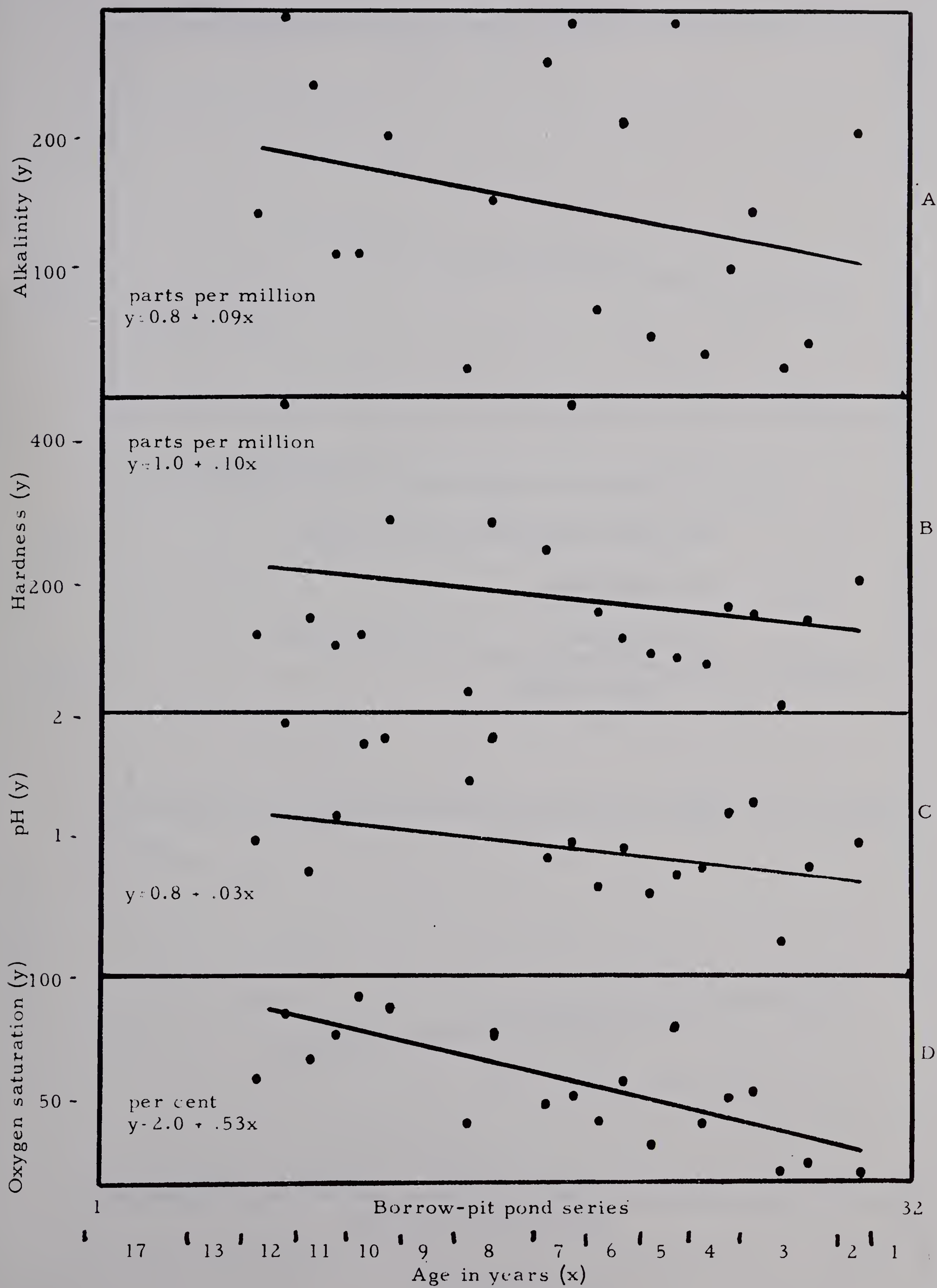
Figure 14. Changes in the seasonal ranges of oxygen saturation, pH, hardness, and alkalinity with pond age.

A. Alkalinity expressed in terms of calcium carbonate.

B. Hardness expressed in terms of calcium carbonate.

C. Hydrogen ion concentration.

D. Oxygen saturation.



Alkalinity (y)
200
100
parts per million
y = 0.8 + .09x
A
Hardness (y)
400
200
parts per million
y = 1.0 + .10x
B
pH (y)
2
1
y = 0.8 + .03x
C
Oxygen saturation (y)
100
50
per cent
y - 2.0 + .53x
D
1
Borrow-pit pond series
32
17 13 12 11 10 9 8 7 6 5 4 3 2 1
Age in years (x)

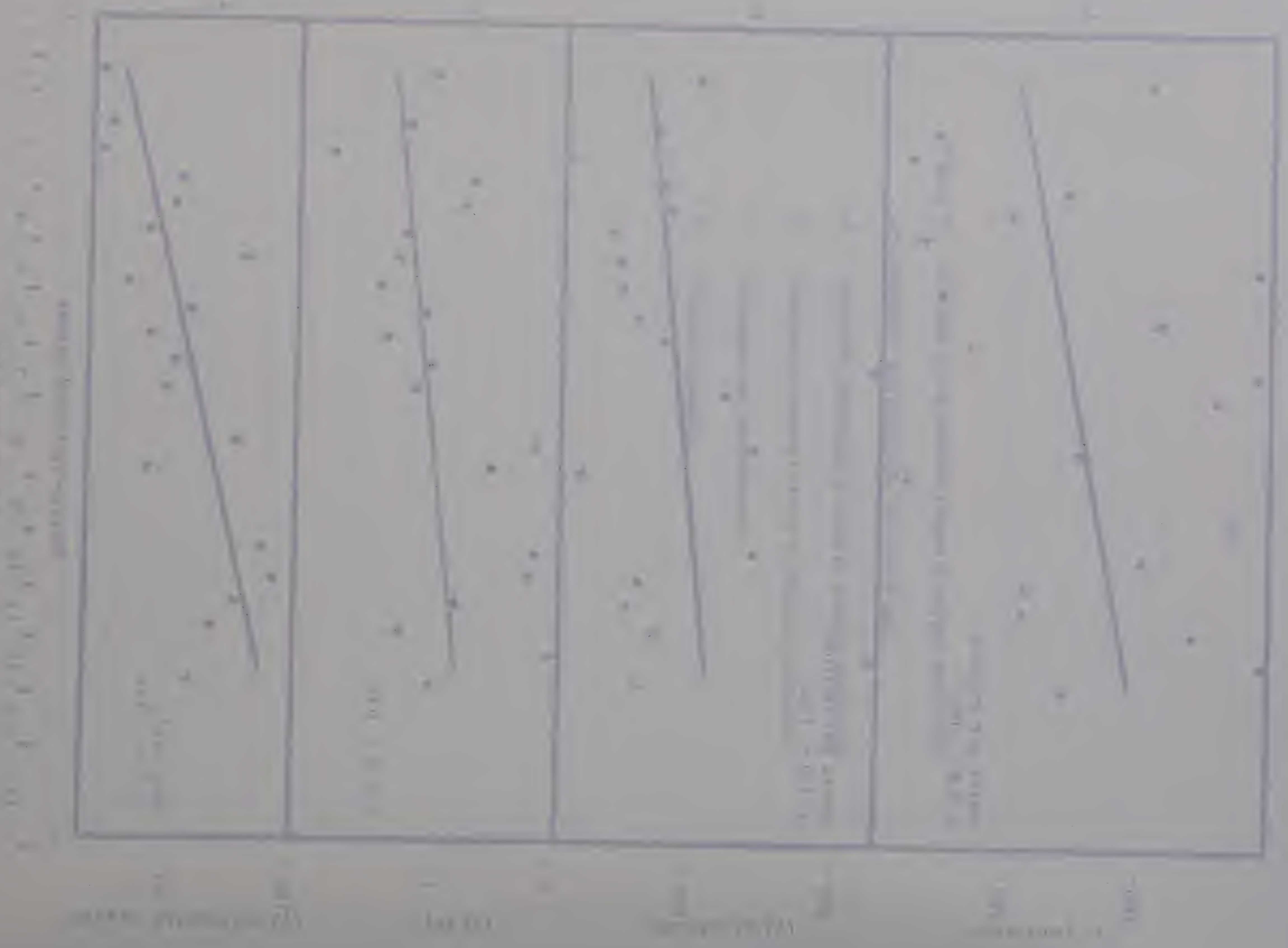
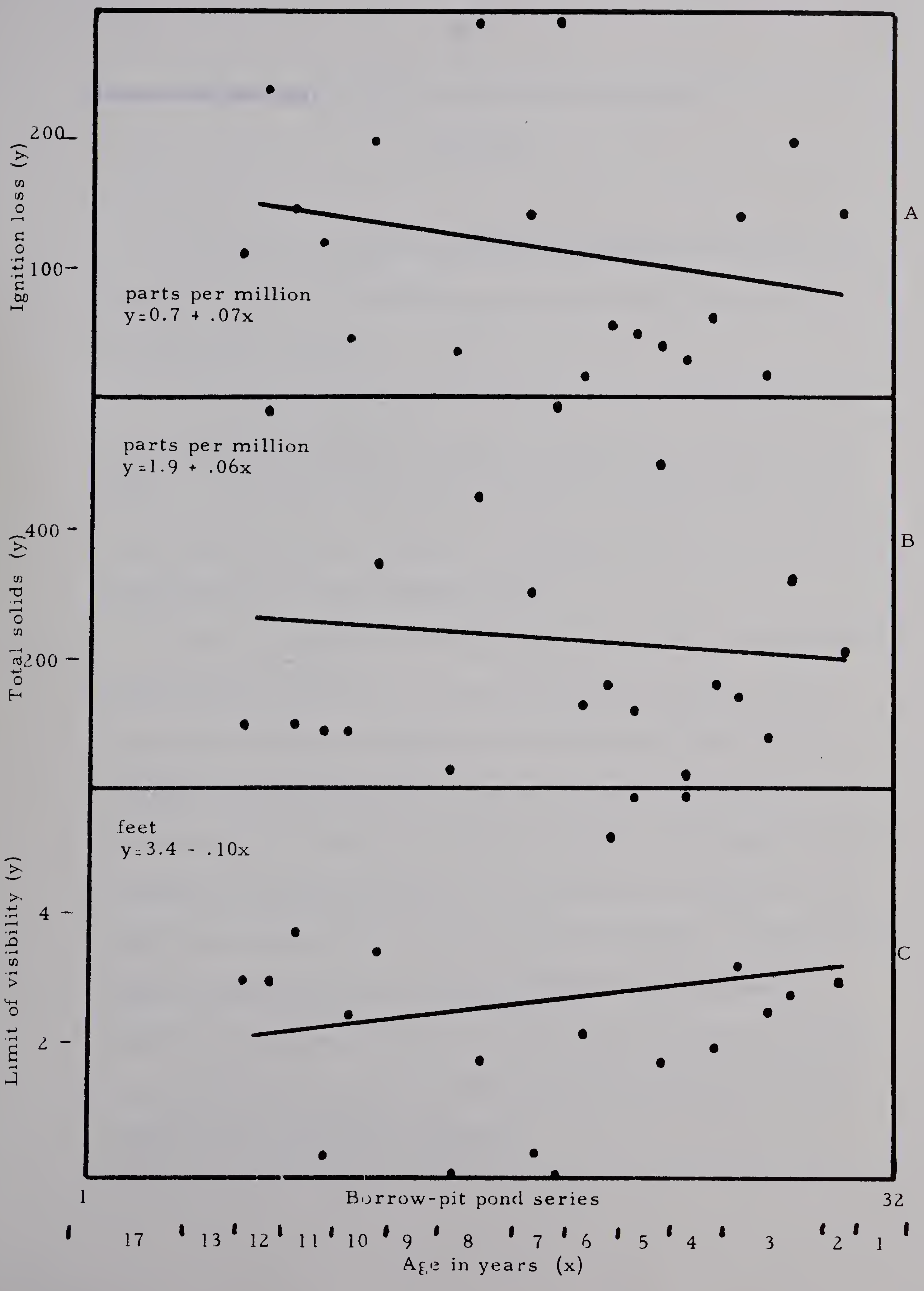


Figure 15. Changes in the seasonal ranges of limit of visibility, total solids, and ignition loss with pond age.

A. Ignition loss.

B. Total solids.

C. Limit of visibility.


Ignition loss (y)
200
100
parts per million
y=0.7 + .07x
A
parts per million
y=1.9 + .06x
Total solids (y)
400
200
B
feet
y=3.4 - .10x
Limit of visibility (y)
4
2
C
1
Borrow-pit pond series
32
17
13
12
11
10
9
8
7
6
5
4
3
2
1
Age in years (x)

increase with pond age.

VI. THE OSTRACODE FAUNA OF THE BORROW-PIT PONDS

1. General remarks

It seems obvious that both neontology and paleontology would benefit from the use of a single set of diagnostic characters for the identification and classification of the fresh-water ostracodes.

The first zoologists to work on the group found that a detailed description of the carapace was sufficient to characterize the species that were encountered. Similarly, micropaleontologists working with the fossil material found that these same criteria "provide a very adequate set of diagnostic characters for classification and identification". (Sylvester-Bradley, 1941).

A shift in emphasis from shell morphology to strictly soft parts (appendages and body structure) was made by several well-known later zoologists which was unfortunate for micropaleontologists as well as the non-specialized zoologists. Their descriptions sometimes include only a crude outline drawing of the carapace, which has been found to be inadequate for comparative purposes. They neglect the muscle-scar pattern, the external ornamentation, the condition of the duplicature and the marginal structures as well as the general shape of the carapace. As a result of this failure to recognize the value of a coordinated effort in describing species, this group of workers inadvertently isolated themselves from the wealth of paleontological information which is the most important key to the realization of the modern taxonomic aim, a phylogenetic classification.

Identifications of the species encountered during this study were made using previously published descriptions based upon shell morphology. The morphological characters used as a basis of identification are illustrated in Figure 16. A simple taxonomic key is given in Appendix F for the species taken from the borrow-pits.

2. A systematic record of the species

The classification and definitions of the represented taxa down to generic rank are given in the Treatise on Invertebrate Paleontology, Part Q (Moore, 1961).

Families, sub-families, and genera are listed with the name of the original author, the date of publication, and the reference page number from the Treatise.

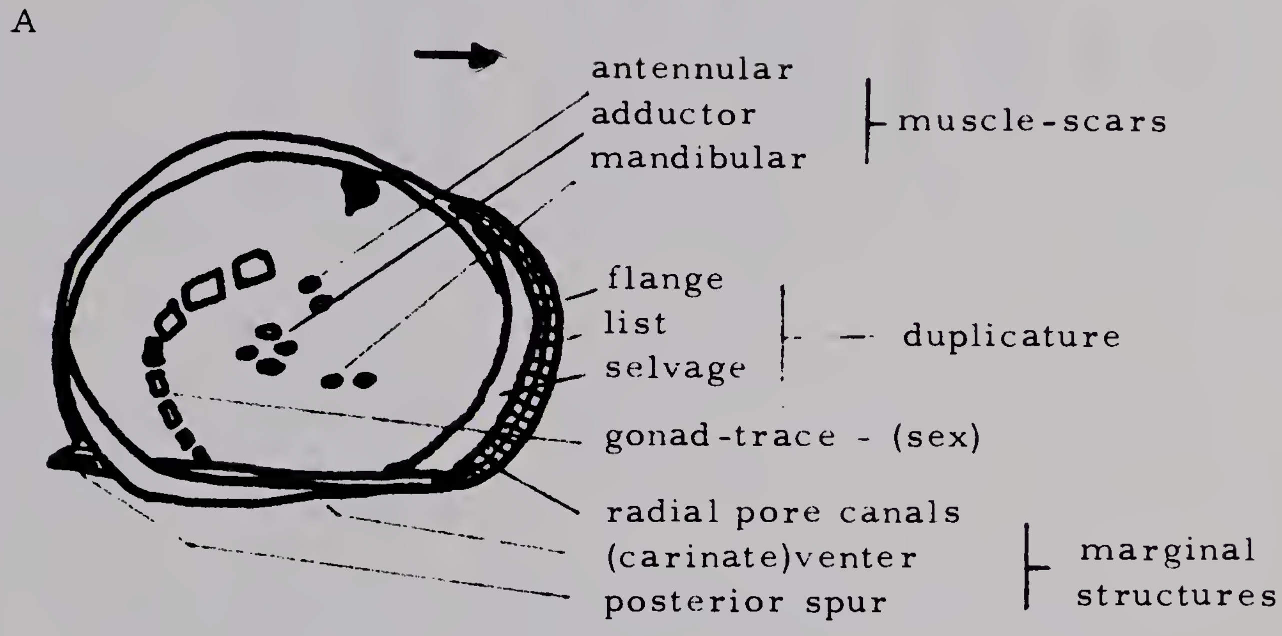
When identifying the specimens, an attempt was made to review critically the available descriptions of the species encountered and to compare these descriptions with those of species which are frequently put in synonomy. A synopsis of this review is given in Table IV.

The descriptions reviewed fell into three categories with regard to the specimens. In the first category are those that adequately describe the specimens. The second category includes those descriptions given for the same species but do not adequately describe the specimens in terms of the diagnostic characters used in this study. The third category contains all those descriptions which seem to fit the specimens but are given to characterize different species, i.e., to erect synonyms.

Thus, Table IV can be used to gauge the reliability of the identification as well as the complexity of the synonomy for a given species. For example, Notodromas monacha (Müller, 1776) Liljeborg, 1853, is readily identifiable on

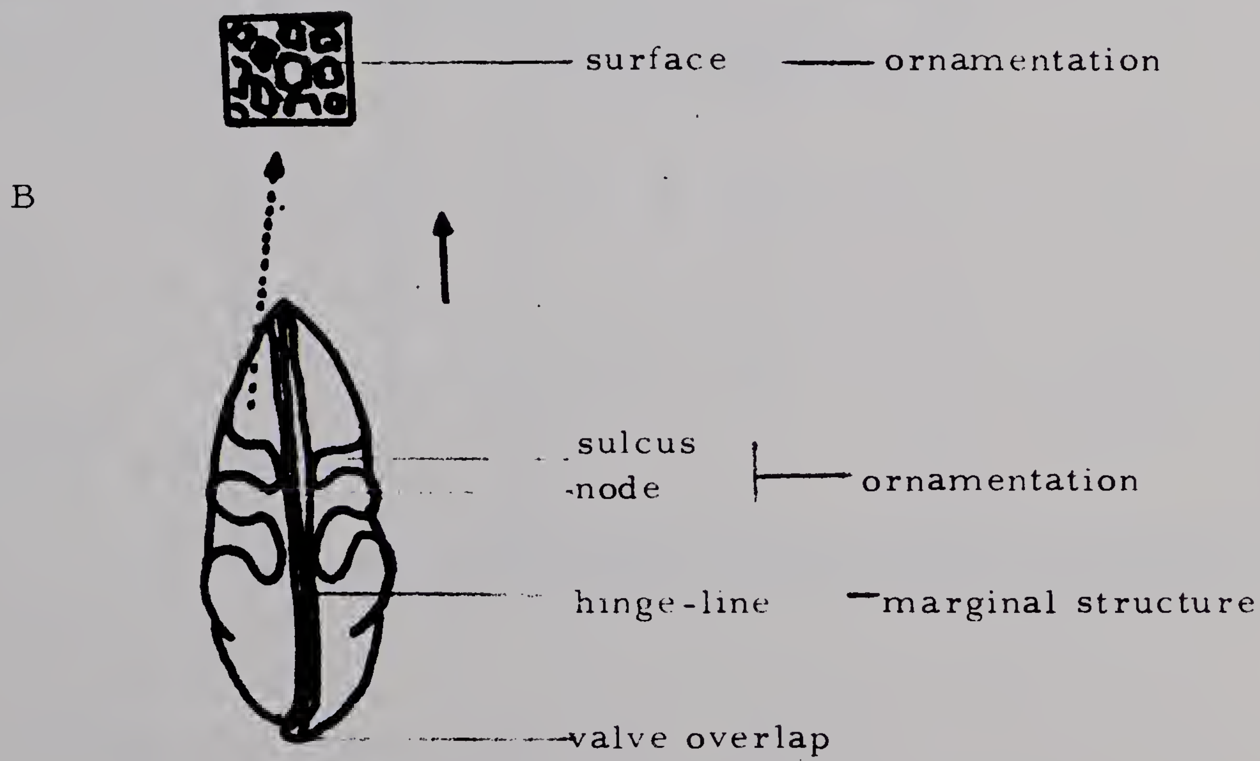
Figure 16. Diagnostic characters used in identification.

Notodromas monacha (female) (lateral interior view)



X50

Ilyocypris bradyi (dorsal view)



X50

Other diagnostic characters: general shape and outline,
hinge structure
marginal tubercles

Table IV. A synopsis of the available species descriptions. Original author and date of publication are taken from the authors of the descriptions available and are not included in the Literature Cited.

Comparison of specimens with descriptions:

1 -no difference

2 - slight difference

3 -synonymous desc.

Descriptions Date	Author	*Cypris pubera*	*Cyprinotus incongruens*	*Cypridopsis vidua*	*Potamocypris smaragdina*	*Cyclocypris ovum*	*Cyclocypris serena*	*Candona candida*	*Candona albicans*	*Candona rostrata*	*Candona suburbana*	*Candona crogmaniana*	*Ilyocypris bradyi*	*Notodromas monacha*
1889	Brady & Norman			1				2		1				1
1897	Sharpe		2	1	3									
1903	Sharpe	2		1	2									1
1908	Sharpe		1			3			3				1	1
1928	Sars	1	3	3		1	1	1	1				1	1
1933	Furtos		1	1	1	2	3		3			1	1	
1935	Furtos						3							
1941	Dobbin	2	2	1	1	2	3	1	3	3				1
1941	Sylvester-Bradley	2						1						
1942	Hoff		1	1	2	3	3		2	1	1	1	1	1
1957	Tressler										3	2		
1960	Winkler										3	2		
1961	Moore (ed.)										1			
1963	Staplin			1	2	2	3	1	1	3	3	2	1	
Original author and date of publication		Müller, 1776	(Ramdohr, 1808) Turner, 1895	(Müller, 1776) Brady, 1867	(Vàvra, 1891) Daday, 1900	(Jurine, 1820) Müller, 1912	(Koch, 1838) Sars, 1928	(Müller, 1776) Vàvra, 1891	Brady, 1864	Brady & Norman, 1889	Hoff, 1942	Turner, 1894	Sars, 1890	(Müller, 1776) Liljeborg, 1853

the basis of any of the descriptions reviewed, whereas *Cyclocypris serena* (Koch, 1838) Sars, 1928, has a history of confusion with *C. forbesi* Sharpe, 1897, as well as being occasionally assigned to such new species as *C. ampula* Furtos, 1933, and *C. washingtonensis* Dobbin, 1941.

Since the immediate aim is identification based on previously published descriptions there is no need to rewrite descriptions for each species nor is there a need to reproduce long synonymies, as both tasks have been done many times by previous workers, some of whom are listed in Table IV.

Plates I to IV, which contain 50 photomicrographs, illustrate the 13 species identified during this study. Magnifications are all about X50.

All families encountered belong to the Superfamily Cypridacea Baird, 1845, (Treatise Q208-211). The classification of these families is arranged as follows:

Family Cypridinae Baird, 1845, (Q211).

Subfamily Cypridinae Baird, 1845, (Q213).

Genus *Cypris* Muller, 1776, (Q213).

1. *Cypris pubera* Muller, 1776

Remarks: Plate I, Figures 1 - 5.

The differences that exist between the descriptions of *C. pubera* and these specimens arise from the fact that no adult specimens were collected.

Genus *Cyprinotus* Brady, 1886, (Q217).

2. *Cyprinotus incongruens* (Ramdohr, 1808) Turner, 1895.

Remarks: Plate I, Figures 6 - 7.

Only two dissimilar live specimens of this species were collected, from two different ponds. Disarticulated valves similar to both were recovered from both localities. Relative size and slight variation in outline indicate that they represent the male and female of this species.

Subfamily Cypridopsinae Kaufmann, 1900 (Q230).

Genus _Cypridopsis_ Brady, 1867, (Q230).

3. _Cypridopsis_ _vidua_ (Muller, 1776) Brady, 1867

Remarks: Plate I, Figures 8 - 14.

The specimens identified as _C_. _vidua_ during this study demonstrate the variability of this species.

Genus _Potamocypris_ Brady, 1870, (Q230).

4. _Potamocypris_ _smaragdina_ (Vavra, 1891), Daday, 1900

Remarks: Plate II, Figures 1-7.

Both sexes and three or four intermediate instars were collected at numerous localities. Most of the discrepancies found in the literature seems to result from the ignoring of allometric development and sexual dimorphism.

Family Cyclocyprididae Kaufman, 1900. (Q234).

Genus _Cyclocypris_ Brady & Norman, 1889, (Q234)

5. _Cyclocypris_ _ovum_ (Jurine, 1820) Muller, 1912.

Remarks: Plate II, Figures 12 - 15.

This species is consistently confused with _C_. _laevis_ and _C_. _sharpei_. The most conspicuous difference is apparent when viewed dorsally. _C_. _ovum_ is typically oval in dorsal outline whereas the other two species are egg-shaped.

6. *Cyclocypris serena* (Koch, 1838) Sars, 1928.

Remarks: Plate II, Figures 8 - 11.

The specimens included in this taxon fit several other specific definitions, as indicated above. On the basis of the earliest description (Sars, 1928), they are placed in *C. serena*.

Family Candonidae Kaufmann, 1900, (Q234).

Genus *Candona* Baird, 1845, (Q234).

7. *Candona candida* (Muller, 1776) Vavra, 1891.

Remarks: Plate III, Figures 1 - 3.

In the Treatise, Part Q, Candona is replaced by Eucandona. This error is corrected in this synopsis on the basis of an emendation in the Journal of Paleontology, Vol. 36, 1962; p. 838.

While the descriptions indicate that *C. candida* is moderately variable in terms of some of the diagnostic characters, the specimens studied showed little variation.

8. *Candona albicans* Brady, 1864.

Remarks: Plate III, Figure 4.

This species is often confused with *C. rostrata*. The specimens assigned to *C. albicans* here were not associated ecologically with specimens which clearly fitted the descriptions of *C. rostrata*, so the possibility of them being instars of that species was considered remote.

9. *Candona rostrata* Brady & Norman, 1889.

Remarks: Plate III, Figures 8 - 9.

PLATE SECTION

PLATE I

All magnifications X50

Figures 1 - 5 - *Cypris pubera*.

1 - Right valve exterior view, instar.

2 - Right valve interior view, instar.

3)
4)- A series of three instars showing
5) surficial ornamentation.

Figures 6 - 7 - *Cyprinotus incongruens*

6 - Left valve exterior view of male.

7 - Right valve exterior view of female.

Figures 8 - 14 - *Cypridopsis vidua*

8 - Lateral view showing internal morphology.

9)- Dorsal views contrasting size, shape and
10) color pattern of three common varieties.
14)

11 - Left valve exterior view showing muscle scars and punctae.

12 - Left valve interior view showing broad anterior duplicature.

13 - Ventral view of a 'variegated' specimen.

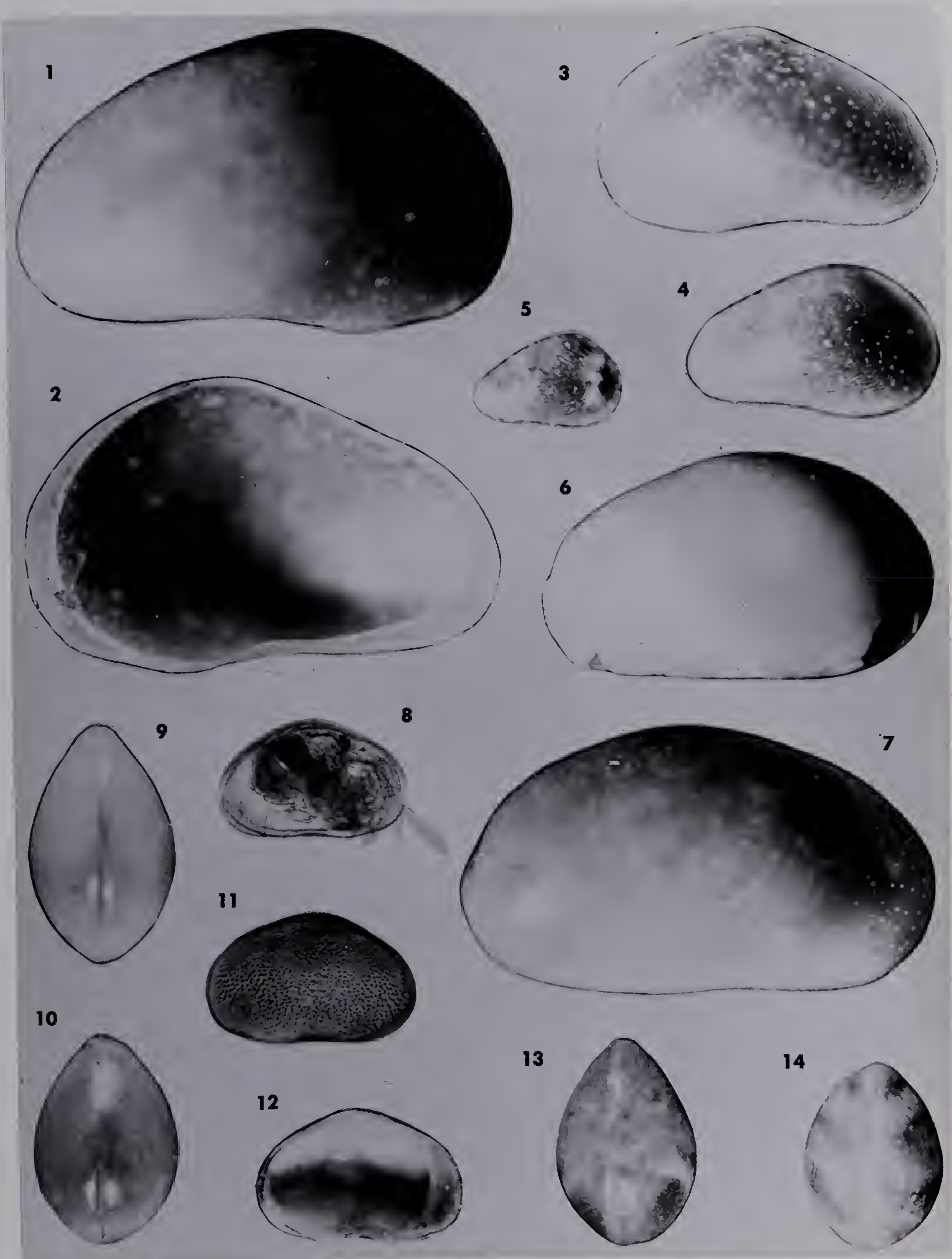


PLATE II

All magnifications X50

Figures 1 - 7 - Potamocypris smaragdina

1) - Lateral views showing dorsal valve overlap,
2) - muscle scar pattern and hairs on the valve (1).

3) - Lateral view showing internal morphology, female.

4) - Dorsal view.

5)- A series of three instars showing
6) allometric development.
7)

Figures 8 - 11 - Cyclocypris serena

8 - Lateral view showing internal morphology

9 - Left valve interior view.

10 - Right valve exterior view.

11 - Dorsal view.

Figures 12 - 15 - Cyclocypris ovum

12 - Lateral view showing internal morphology.

13 - Right valve exterior view.

14 - Right valve interior view.

15 - Dorsal view.

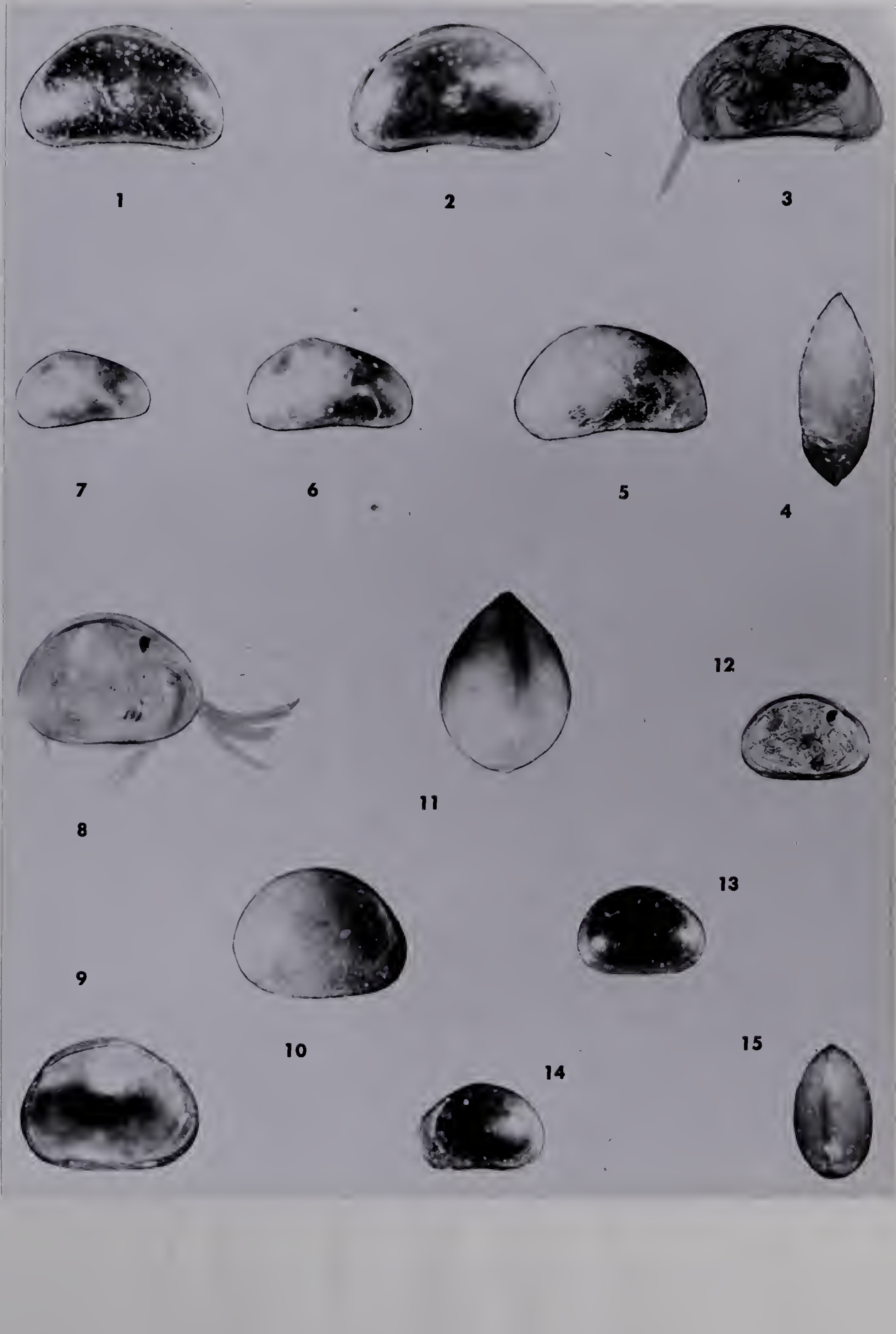


PLATE III

All magnifications X50

Figures 1 - 3 - Candona candida

1 - Left valve interior view.

2 - Dorsal view.

3 - Right valve exterior view.

Figure 4 - Candona albicans

4 - Lateral view showing left valve.

Figures 5 - 7 - Candona crogmaniana

5 - Lateral view of left valve showing valve overlap.

6 - Dorsal view.

7 - Right valve interior view.

Figures 8 - 9 - Candona rostrata

8 - Right valve interior view.

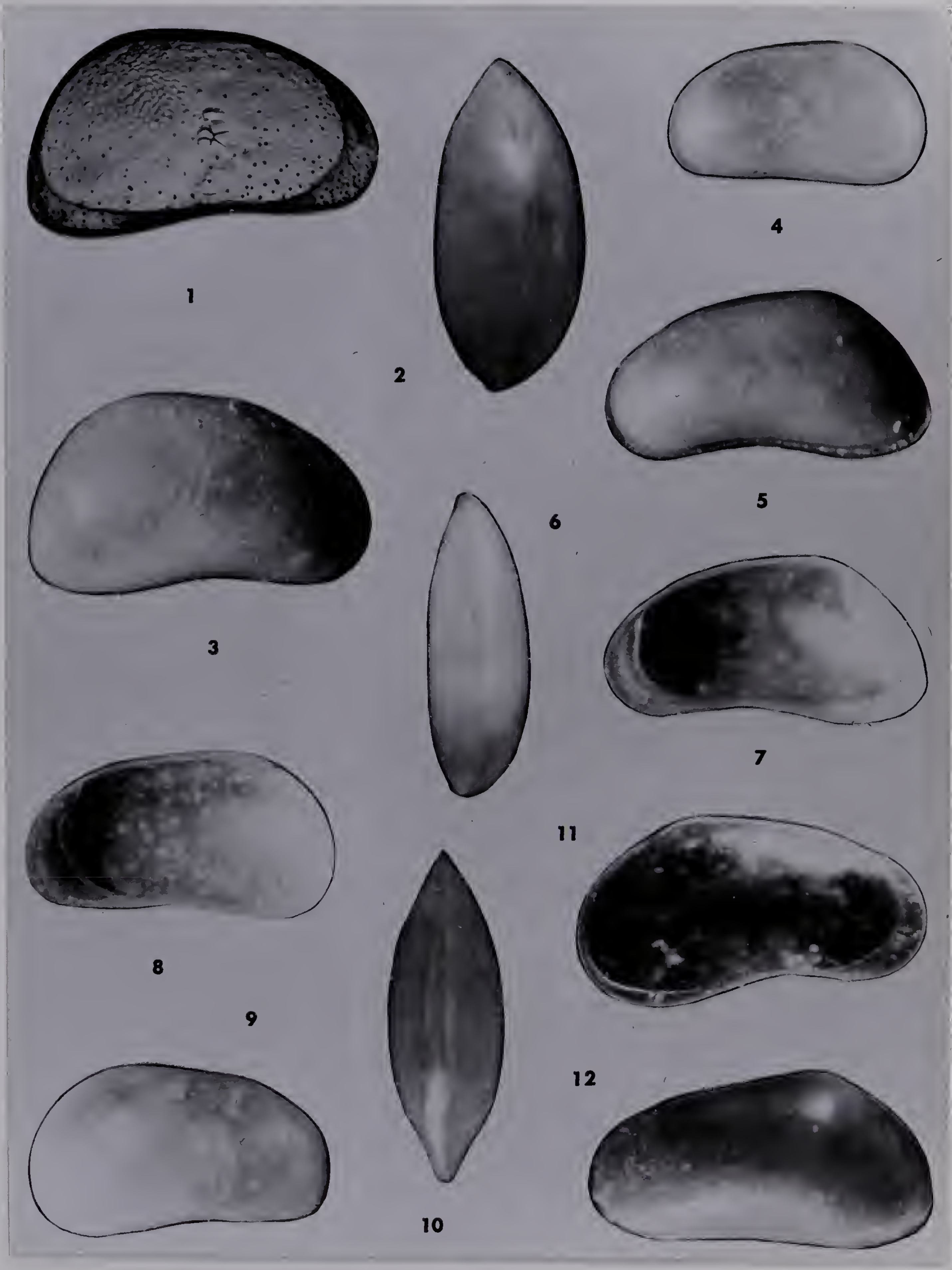
9 - Lateral view showing right valve.

Figures 10 - 12 - Candona suburbana

10 - Dorsal view of female.

11 - Left valve interior view of male.

12 - Lateral view showing left valve of female.


1
2
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12

PLATE IV

All magnifications X50

Figures 1 - 3 - *Ilyocypris bradyi*

1 - Right valve exterior view.

2 - Dorsal view.

3 - Right valve interior view.

Figures 4 - 9 - *Notodromas monacha*

4 - Lateral view showing internal morphology of male.

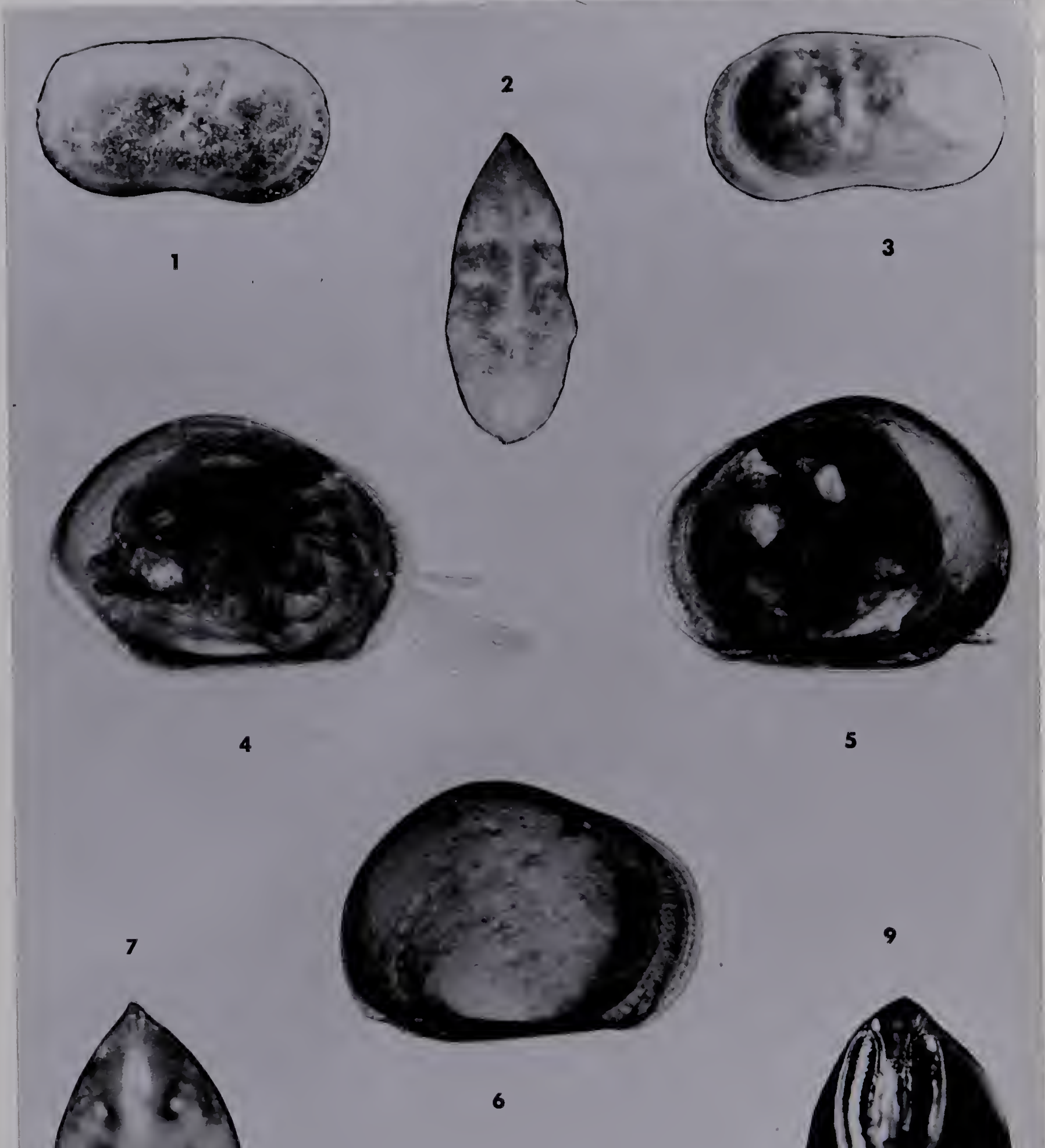
5 - Lateral view showing internal morphology of female.

6 - Left valve interior view of female.

7 - Dorsal view of male.

8 - Lateral view of an instar.

9 - Ventral view of male showing carinate venter.


1
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4
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6
7
8
9

The adults are larger in size than C. albicans and in dorsal view the anterior margin is characteristically pinched, forming a sharp point.

10. Candona suburbana Hoff, 1942.

Remarks: Plate III, Figures 10- 12.

Hoff's description and illustrations are quite complete and adequately characterize these specimens.

11. Candona crogmaniana Turner, 1894.

Remarks: Plate III, Figures 5 - 7.

The specimens assigned to this taxon do not fit all the descriptions as indicated in Table IV, but on the bases of Furtos's (1933) and Hoff's (1942) descriptions they are placed in this species.

Family Ilyocyprididae Kaufmann, 1900 (Q239).

Subfamily Ilyocypridinae Kaufmann, 1900, (Q239).

Genus Ilyocypris Brady & Norman, 1889, (Q239).

12. Ilyocypris bradyi Sars, 1890.

Remarks: Plate IV, Figures 1 - 3.

The specimens assigned to I. bradyi fit all the available descriptions of this species.

Family Notodromadidae Kaufmann, 1900 (Q245).

Genus Notodromas Liljeborg, 1853.

13. Notodromas monacha (Muller, 1776) Liljeborg, 1853.

Remarks: Plate IV, Figures 4 - 9.

A very well-defined and distinct species represented in the

collection by instars and both male and female individuals.

3. Distribution of the species

(a) Regional and seasonal occurrences: A qualitative summary of the occurrences in North America is given in tabular form (Table V). The occurrences in borrow-pit ponds are compared with those from other geographic areas of North America. Although this synopsis is clearly incomplete, it does serve to underline the wide distribution which characterizes most fresh-water species. Only one out of the 13 species recovered from the borrow-pit ponds had not been originally described by European workers (Candona suburbana Hoff, 1942; Pl. III, Figures 10 - 12).

The absence from the previous North American seasonal records of those species which were collected during February is significant in that it reflects the amount of basic survey work that has yet to be done. Similarly, ontological studies which are of primary importance to future population studies have been neglected by most American workers. This neglect is made manifest by the absence of records on the seasonal occurrence of instars.

(b) Occurrences in borrow-pit ponds: Table VI shows the distribution of the species in a series of ponds ranging in age from 1 to 17 years. The ponds, numbered 1 to 32, are arranged in a chronological sequence from those constructed in 1947-48 to those constructed in 1964. Twenty out of the 32 ponds were sampled during each season, and the remaining 12 were sampled during two or three seasons. In all cases where sampling was not done seasonally the winter sample was not collected, and in the cases where only two samples were collected the

Table V. Qualitative regional and seasonal occurrences of live specimens.

x - Adults
O - Instars
⊗ - Both Adults and instars

Geographic region and seasons. / Species		*Cypris pubera*	*Cyprinotus incongruens*	*Cypridopsis vidua*	*Potamocypris smaragdina*	*Cyclocypris ovum*	*Cyclocypris serena*	*Candona candida*	*Candona albicans*	*Candona rostrata*	*Candona suburbana*	*Candona crogmaniana*	*Ilyocypris bradyi*	*Notodromas monacha*
Western Canada		⊗	x	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	x	⊗	⊗
*Alberta	May			⊗	⊗	⊗	⊗						O	
	July	O	x	⊗	⊗	⊗	⊗	O			x		⊗	⊗
	October			⊗	⊗	⊗	⊗	⊗		x	⊗	x	x	
	February			x		x	⊗	⊗	⊗		⊗			
Saskatchewan		⊗	x	⊗	⊗	⊗	⊗	⊗	x	⊗	?	x	x	x
	Spring	⊗		⊗	⊗	⊗	⊗	O		⊗				
	Summer	⊗		⊗	⊗	⊗	⊗	O		⊗				
	Autumn			⊗	⊗	⊗	⊗	⊗		⊗				
	Winter					x	x							
Manitoba (no seasonal records)			x	x	x	x		x						
United States		x	x	x	x	x	x	x	x	x	x	x	x	x
	Spring		x	x	x	x	x		x		x	x	x	x
	Summer		x	x	x	x	x		x		x		x	x
	Autumn		x	x	x	x	x					x	x	x
	Winter			x		x	x					x		
North American (seasonal distribution)														
	Spring	⊗	x	⊗	⊗	⊗	⊗	O	⊗	⊗	x	x	⊗	x
	Summer	⊗	x	⊗	⊗	⊗	⊗	O	x	⊗	x		⊗	⊗
	Autumn		x	⊗	⊗	⊗	⊗	⊗		⊗	⊗	x	x	x
	Winter			x		x	⊗	⊗	⊗		⊗	x		

The additional data used in this chart are taken from the publications listed in Table IV, as well as Delorme (1964).

*Only the borrow-pit occurrences are included from Alberta.

spring sample was also not taken. The ponds marked with an asterisk are those where sampling was carried out two or three times.

The Candona spp. entry includes four occurrences of unidentified instars of Candona, plus the five species which are tabulated separately.

Sample numbers and sampling districts are included so that locations may readily be seen by referring to Figure 2.

A frequency table (Table VII) which summarizes Table VI may be used as a guide to determine the overall effect that pond age has on the occurrence of each species. By including the sampling districts, a possible alternative explanation for the distributional patterns based on the physiographic and physico-chemical attributes that are not demonstrably dependent on pond age is made available.

Of the species listed in Table VII, Notodromas monacha, Cyclocypris ovum, Cyclocypris serena, and Cypridopsis vidua, all increase in frequency occurrence with increase in pond age.

Candona spp. deviates from what is apparently a trend in frequency of occurrence which increases with increase in pond age. Potamocypris smaragdina and Ilyocypris bradyi both reach peak frequencies in the 1957-61* age class, while Candona spp. reaches a peak in the 1953-56 age class.

If the assumption that the seral stage of each pond age class is reflected in the ostracode fauna is valid, then these apparent deviations from the overall trends could be explainable on the bases of differences in physiographic and/or physico-chemical preferences of the species in question. In other words, not all species have

*Age classes in this manuscript will be characterized by the dates of construction.

Table VI. Distribution of species in borrow-pit ponds.

Pond Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Sample Number	57	58	60	62	53	54	17	20	12	16	8	10	47	48	28	30
Sampled only 2-3 times	*	*	*	*	*	*							*	*		
Year of Construction	47-48?				52		53		54		55		56		57	
Age of pond (years)	17				13		12		11		10		9		8	
Cypris pubera																
Cyprinotus incongruens																
Cypridopsis vidua	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Potamocypris smaragdina				x	x	x		x		x			x		x	x
Cyclocypris ovum	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x
Cyclocypris serena	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Candona candida			x		x		x	x	x	x		x				
Candona albicans									x				x			
Candona rostrata												x				
Candona suburbana					x		x	x	x	x		x				
Candona crogmaniana							x			x						
*Candona spp.			x	x	x		x	x	x	x		x	x		x	x
Ilyocypris bradyi		x										x	x			
Notodromas monacha	x	x	x		x	x	x		x	x						
Sampling Districts	Central						Western								Central	

Pond Number	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Sample Number	31	32	33	38	39	46	45	40	42	5	22	6	61	25	51	52
Sampled only 2-3 times	*												*		*	*
Year of Construction		58		59		60		61		62				63	64	
Age of pond (years)		7		6		5		4		3				2	1	
Cypris pubera							x									
Cyprinotus incongruens								x								x
Cypridopsis vidua	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x
Potamocypris smaragdina	x	x	x		x	x	x		x	x	x		x	x		x
Cyclocypris ovum	x	x	x	x								x				
Cyclocypris serena	x	x	x	x	x	x	x	x	x	x	x	x	x			
Candona candida	x			x	x						x					
Candona albicans																
Candona rostrata																
Candona suburbana																
Candona crogmaniana																
*Candona spp.	x			x	x		x				x					
Ilyocypris bradyi	x					x	x	x		x				x		
Notodromas monacha		x														
Sampling Districts										Eastern						

* Includes all identified species plus unidentified Candona instars.

Table VII. Per cent frequency of occurrence of species.

Age classes (dates of origin)	1947 - 48 (?) - 1952		1953 - 1956		1957 - 1961		1962 - 1964	
Sampling districts	Central		Western		Central		Eastern	
No. of ponds per age class	6		8		11		7	
Species	No. of occur	% frequency	No. of occur.	% frequency	No. of occur.	% frequency	No. of occur.	% frequency
Cypris pubera	0	0	0	0	1	9	0	0
Cyprinotus incongruens	0	0	0	0	1	9	1	14
Cypridopsis vidua	6	100	8	100	11	100	6	86
Potamocypris smaragdina	3	50	3	38	9	82	5	71
Cyclocypris ovum	6	100	7	88	6	55	1	14
Cyclocypris serena	6	100	8	100	11	100	4	64
Candona candida	2	33	5	62	3	27	1	14
Candona albicans	0	0	2	25	0	0	0	0
Candona rostrata	0	0	1	12	0	0	0	0
Candona crogmaniana	0	0	2	25	0	0	0	0
Candona suburbana	1	17	5	62	0	0	0	0
Candona spp.	3	50	6	75	6	55	1	14
Ilyocypris bradyi	1	17	2	25	4	36	2	28
Notodromas monacha	5	83	3	38	1	9	0	0

their ecological optimum in the first or last age class and, hence, would show peak frequency of occurrence in one of the intermediate age classes.

This problem will be discussed further after the introduction of some quantitative data on the relative abundances of the species and an attempt is made to correlate the seral differences in the environment with the apparent successional changes in the fauna.

(c) Quantitative distribution: Relative seasonal abundances are given in Figure 17 for Cyclocypris serena, Cypridopsis vidua, Cyclocypris ovum, Ilyocypris bradyi, Potamocypris smaragdina, Notodromas monacha, and Candona spp.

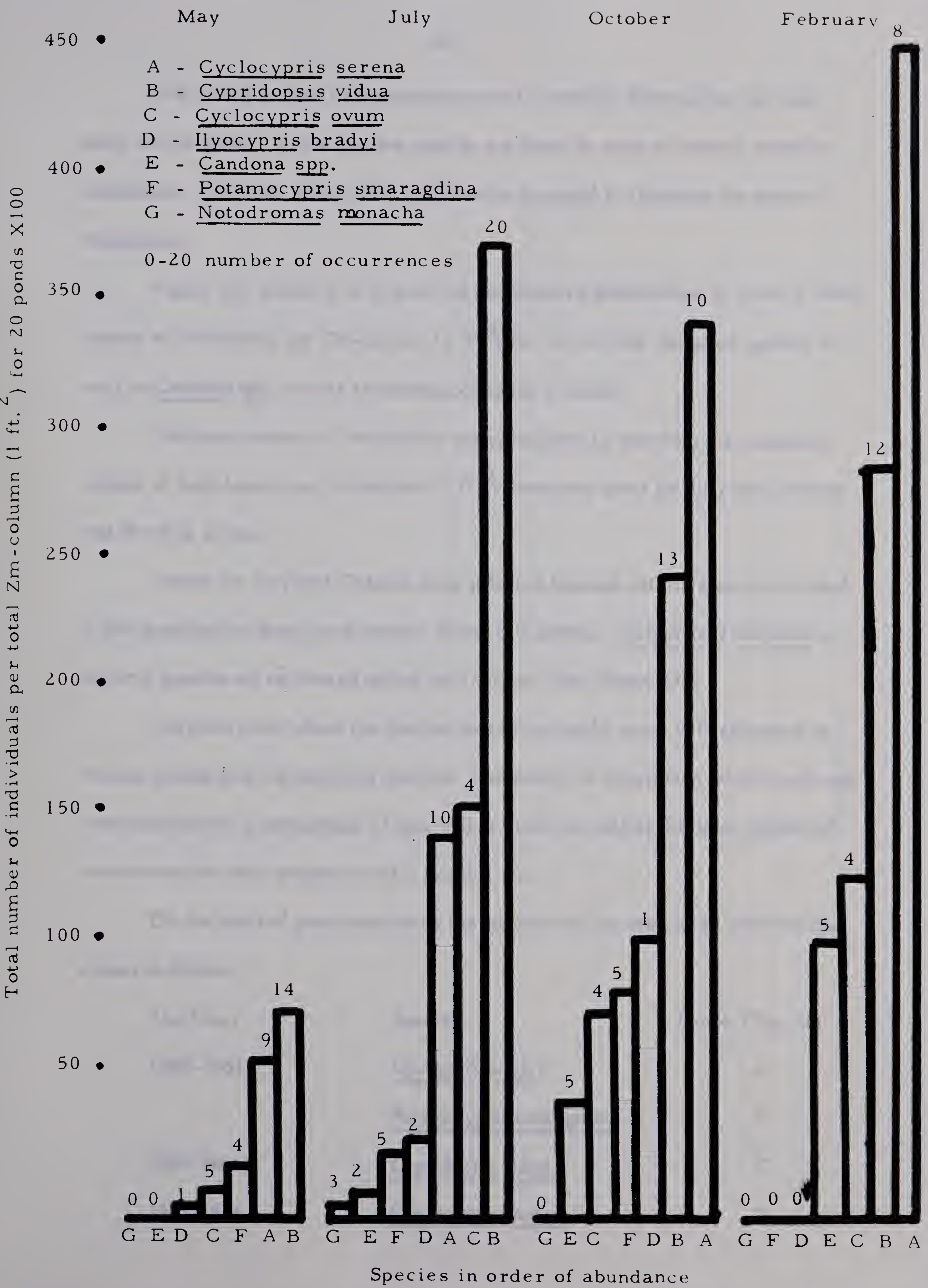
Since ostracodes cannot be strictly categorized as benthic or planktonic, it was necessary to convert the counts made of each species from both the plankton hauls and the dredge samples to units that were additive. This conversion makes it possible to get a fairly accurate relative census of a given species population at the time of sampling for any number of ponds.

Twenty ponds selected to give the maximum diversity of fauna were sampled each season and the number of live adults and instars which inhabited one square foot of bottom and the water column above this area in the deepest part of the pond was calculated for each species on the basis of the samples taken.

The relative seasonal totals were then computed by adding the number of individuals calculated to occupy each Zm-column (1 ft.^{2}) for all 20 ponds.

Thus, the resulting bar graphs (Figure 17) are comparative as each bar represents the total number of individuals inhabiting an equal volume of habitat.

Figure 17. Relative seasonal abundances.


May
July
October
February
450
400
350
300
250
200
150
100
50
A - Cyclocypris serena
B - Cypridopsis vidua
C - Cyclocypris ovum
D - Ilyocypris bradyi
E - Candona spp.
F - Potamocypris smaragdina
G - Notodromas monacha
0-20 number of occurrences
Total number of individuals per total Zm-column (1 ft.²) for 20 ponds X100
0 0 1 5 4 9 14
G E D C F A B
3 2 5 2 10 4 20
G E F D A C B
0 5 4 5 1 13 10
G E C F D B A
0 0 0 5 4 12 8
G F D E C B A
Species in order of abundance

The actual number of occurrences out of a possible 20 are given for each entry on the graph. In the key the species are listed in order of overall maximum abundance. For each season they are likewise arranged to illustrate the order of abundance.

Figure 18, graphs A to G give the quantitative distributions in terms of mean number of individuals per Zm-column (1 ft.^{2}) for the six most abundant species as well as Candona spp. for the chronological series of ponds.

The mean number of individuals was calculated by totalling the computed number of individuals per Zm-column (1 ft.^{2}) from each pond for July and October and dividing by two.

Counts for July and October were selected because all the species included in the quantitative study were present during this period. Notodromas monacha is the only species not recovered during both seasons (See Figure 17).

The plots show where the species population peaks occur with reference to the age classes and the sampling districts. Frequency of occurrence within each age class expressed as a percentage (Table VII) is shown as well as the total number of occurrences for each species out of a possible 32.

On the basis of peak abundance the species may be associated with the age classes as follows:

Age Class	Species	Graph (Fig. 18)
1962-1964	Ilyocypris bradyi	A
	Potamocypris smaragdina	B
1957-1961	Cypridopsis vidua	C
1953-1956	Cyclocypris serena	D

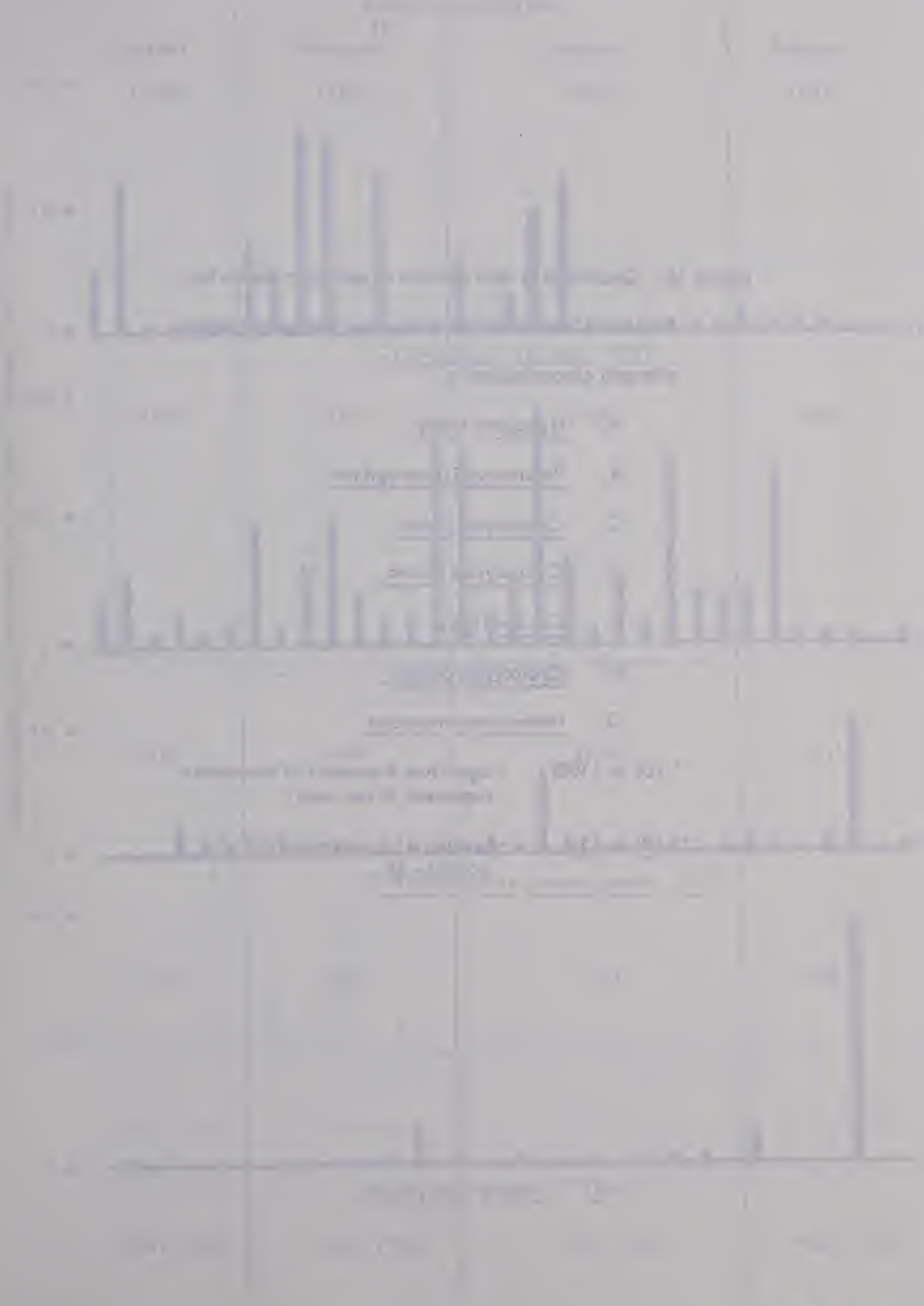


Figure 18. Quantitative distributions of species - means for July and October for the thirty-two borrow-pit ponds arranged chronologically.

A. *Ilyocypris bradyi*

B. *Potamocypris smaragdina*

C. *Cypridopsis vidua*

D. *Cyclocypris serena*

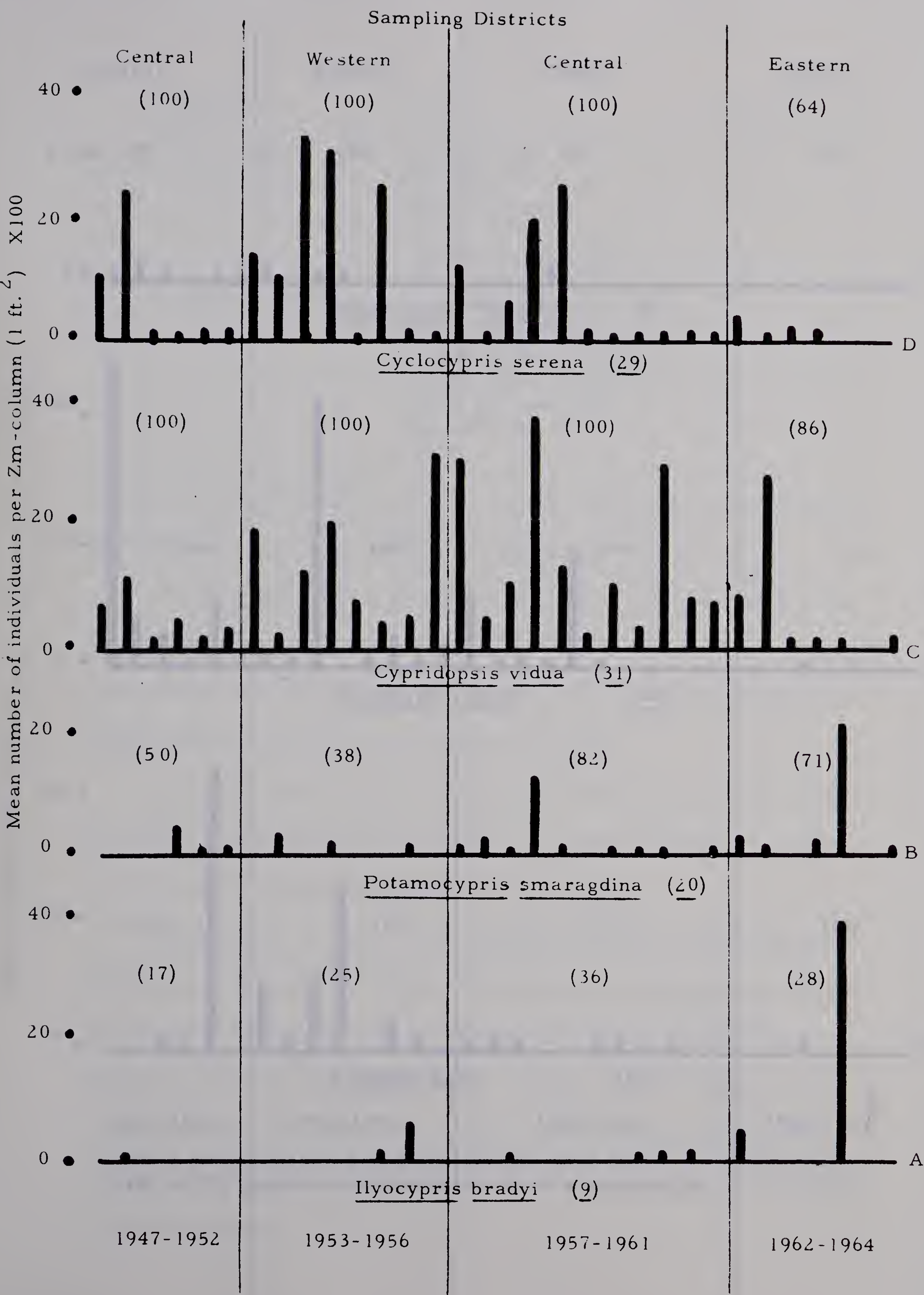
E. *Candona spp.*

F. *Cyclocypris ovum*

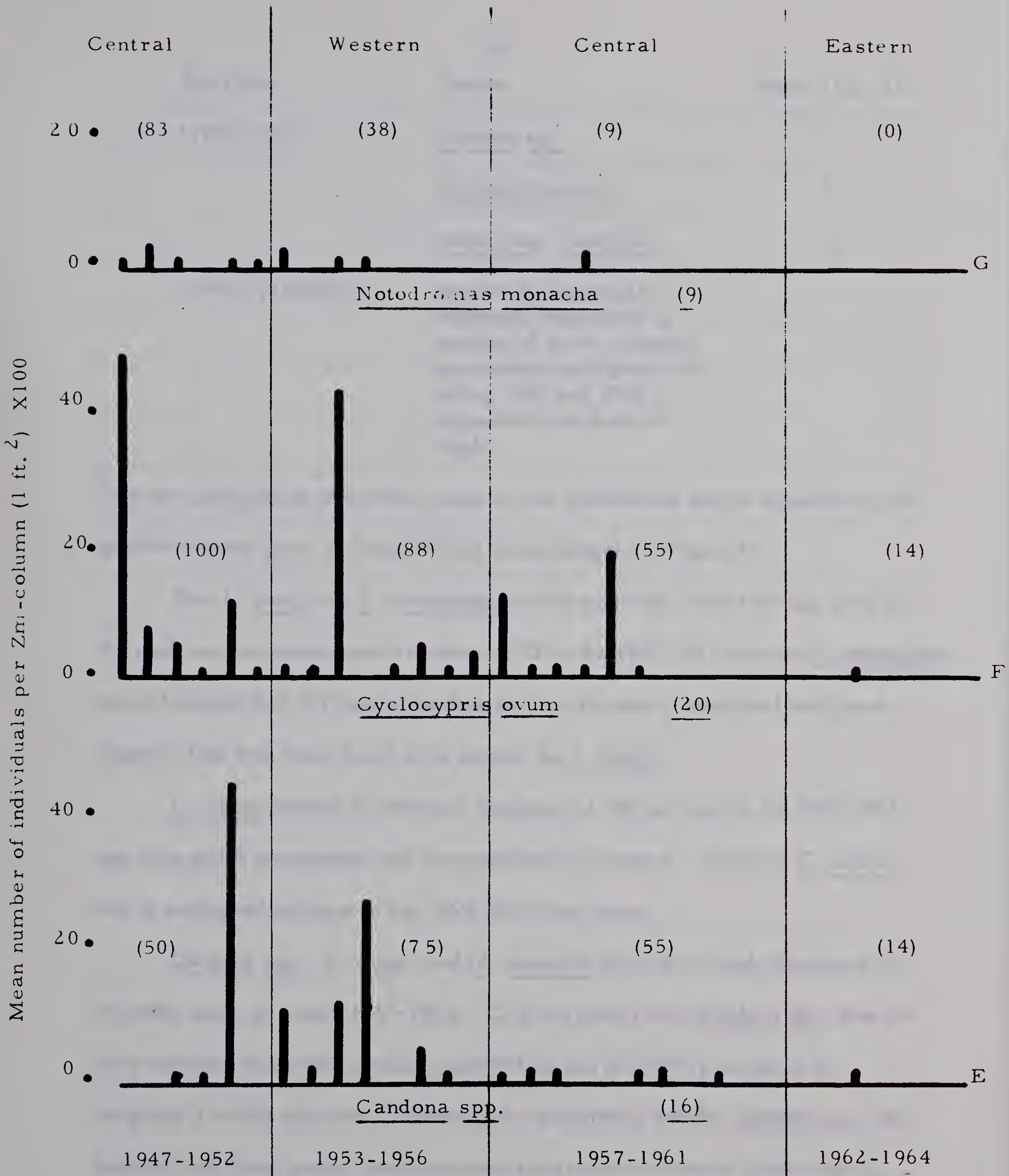
G. *Notodromas monacha*

* (0) to (100) - age class frequency of occurence expressed in per cent.

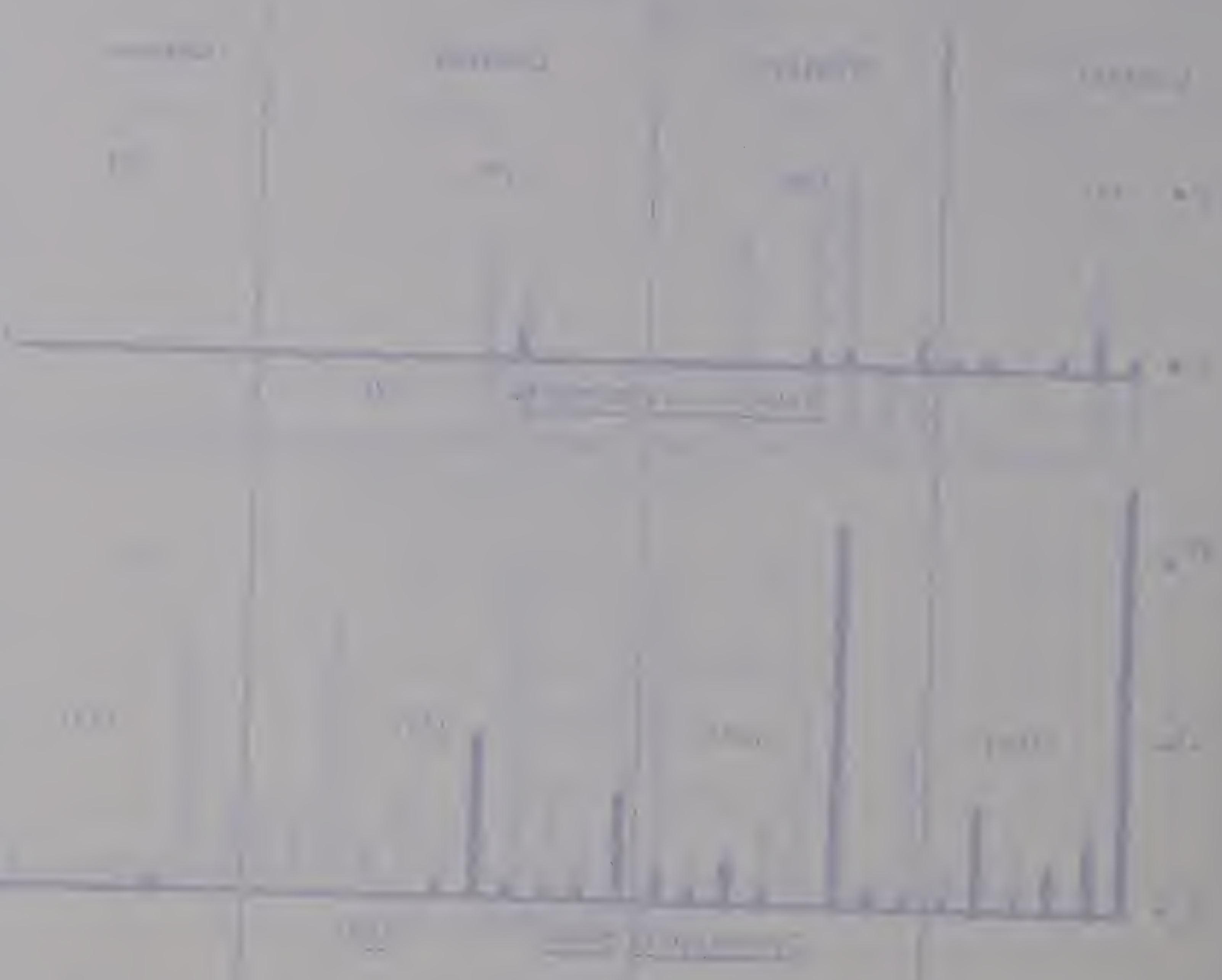
** (9) to (31) - number of occurrences out of a possible 32.



Sampling Districts
Central
Western
Central
Eastern
Mean number of individuals per Zm-column (1 ft.²) X100
40
20
0
(100)
(100)
(100)
(64)
D
Cyclocypris serena (29)
(100)
(100)
(100)
(86)
C
Cypridopsis vidua (31)
(50)
(38)
(82)
(71)
B
Potamocypris smaragdina (20)
(17)
(25)
(36)
(28)
A
Ilyocypris bradyi (9)
1947-1952
1953-1956
1957-1961
1962-1964



*(0) to (100) expressed in per cent; age class frequency of occurrence.
*(9) to (31) number of occurrences out of a possible 32.



Age Class	Species	Graph (Fig. 18)
*1947-1952	Candona spp.	E
	Cyclocypris ovum	F
	Notodromas monacha	G
*1947(?)-1948(?)	Age not documented by Highways Department; a resident of Smith, Alberta, who worked on Highway 44 during 1947 and 1948 suggested these dates of origin.	

This age class-species association based on the quantitative data is supported by the qualitative data given in Table VII and included again in Figure 18.

Both I. bradyi and P. smaragdina are placed in the 1962-1964 age class but the peak per cent occurrence frequency of 82 in the 1957-1961 class for P. smaragdina would indicate that this species tends to be more commonly associated with ponds slightly older than those found to be optimal for I. bradyi.

C. vidua reaches its maximum frequency of 100 per cent in the 1957-1961 age class which corresponds with the quantitative evidence. Similarly C. serena has its ecological optimum in the 1953-1956 class ponds.

Candona spp., C. ovum, and N. monacha attain their peak abundance in the older group of ponds (1947-1952). Of these groups only Candona spp. does not show complete agreement between quantitative and qualitative evidence for assigning it to this age class. However, the qualitative data for Candona spp. may indicate that these species prefer the conditions that characterize ponds slightly younger in age than those characterizing the ponds where C. ovum and N. monacha reach their optimum.

Finally, C. ovum is clearly a more prominent member of the ostracode community than N. monacha among the ponds of the last age class suggesting the absence of conditions optimal for N. monacha within the sampled pond series.

The total number of occurrences out of a possible 32 (Figure 18 A-G) further supports the arrangement of the seven taxa in the order in which they appear above. Those species which prefer the ecological conditions that characterize the oldest and the youngest ponds are more restricted in their distribution than those which inhabit the intermediate pond age classes. The only deviation from this trend is between Candona spp. (Figure 18E) and Cyclocypris ovum (Figure 18F) and this difference of only four out of 32 possible occurrences could be attributable to inadequate sampling.

VII. DISCUSSION

1. General remarks

It is a well-established truth that orderly changes through time characterize community development in an ecosystem. This "orderly process of community change" is referred to as ecological succession (Odum, 1959). Early students of succession such as Shelford (1913), Clements (1916), and others, observed that ecological succession was directional. Hence, after the seral stages are worked out for a given community, predictions as to future changes may be made when the seral stage present at the time of the investigation is ascertained.

The seral stages in an ecological succession are usually defined by indicator species that reflect the physico-chemical condition of the ecosystem. While plants have been used most extensively as ecological indicators in the past there is a definite need to study animal succession in those instances where suitable species are present. One such group of animals are ostracodes, since they have been shown to be reliable indicators and are widely dispersed by the same agents that disperse plant propagules.

Ostracodes have an impressive fossil history, being first recognized in the sediments of the Lower Cambrian. Throughout the Paleozoic, the Mesozoic, and the earlier part of the Cenozoic these organisms have proved to be useful index fossils. However, in the Quaternary where the time interval has been shown to be too short for distinct index species to evolve, there is a need to rely upon paleo-ecological studies to provide a method to reconstruct at least local Pleistocene and post-Pleistocene histories. By approaching the problem locally at the ecol-

ogical level, eventually a mosaic depicting the overall climatic changes should emerge, and with it a useful tool for more extensive correlation.

Since Recent assemblages provide the only reliable firsthand source of ecological information on species' preferences, it is logical that the paleoecologist start his studies with these assemblages, especially when dealing with species that are recognizable throughout the Quaternary. Further, the use of the principle of ecological succession to unify and order this ecological data would make the overall climatic picture easier to reconstruct when enough information to warrant the attempt has been gathered. Succession lends itself to an easy transition from extant communities to fossil assemblages because it has an inherent time dimension that is recorded by a series of seral stages in the former and by stratigraphic positions in the latter. Thus, it is an ideal vehicle for making interpretations based upon the total extant, sub-fossil and fossil assemblage.

Borrow-pit ponds provide a suitable habitat in which to start the study of ostracode succession because the dates of origin are well-documented and the subsequent succession is primary. Also, because of the nature of these ponds, succession proceeds at a measurable rate within a relatively short time interval and the resulting seral stages are readily definable by a definite sequence of dominant ostracode species.

If the predicting of future seral stages for a given pond is a valid procedure, then the chronological series of borrow-pit ponds would simulate actual changes that would characterize any given pond through time, provided the ponds of the series were demonstrably equivalent in gross attributes. Chapters IV, V and VI outline some of the environmental and faunal attributes that appear equivalent as well as

those that give evidence to support the assumption that the changes in this ecosystem is an orderly process in time.

2. Ostracode succession in the borrow-pit ponds.

Succession, like evolution, is a process that defies positive proof. Both of these processes may be only illustrated by attempting to show that the results of the assumed process fit the theory that defines that process. In this case, it has been shown that an orderly change in time has taken place within the borrow-pit ponds.

Faunal studies indicate that there is a recognizable ostracode succession in the borrow-pit ponds (Figure 18A - G). Pioneer species include *Ilyocypris bradyi* and *Potamocypris smaragdina*. Subsequent seral stages are characterized by *Cypridopsis vidua*, *Cyclocypris serena*, *Candona* spp., *Cyclocypris ovum*, and finally *Notodromas monacha*. Since only a 17-year interval was sampled it would be unwise to state that *N. monacha* characterizes the climax stage of the succession in the ponds, but at best, only the last stage represented in the ponds sampled.

Besides the criteria of relative frequency of occurrence and peak abundance, which were used to set up the ostracode succession above, there is a third criterion which may be considered. Since it is reasonable to suggest that only those species which are closely related successionally would occur in the same habitat within any yearly cycle, species collected from the borrow-pit ponds that illustrate mutual associations in occurrence in accordance with the proposed ostracode series would further support the successional theory. These Association groups may be defined statistically by using the chi-square tests for independence and goodness of fit (Steel & Torrie, 1960). Appendix I gives the computations upon which the interpretation of the data was made. Mutual occurrences, ignoring seasonal distribution, are

given in a table in Appendix I. Thirty-two ponds were used as the grand total, hence the maximum number of mutual occurrences for any two species would be 32.

The tests were designed firstly to establish whether or not there was any basis for assuming that the occurrence of a given species was associated with the occurrence of one or more of the other species, and secondly to determine which species were actually associated. In order to make the tests the data were arranged to test two null hypotheses which, for the sake of simplicity, may be designated as $H^o{}_1$ and $H^o{}_2$. Chi-square for independence tests the null hypothesis ($H^o{}_1$) that there is no association between the occurrence of a given species and the occurrence of any other species, against the alternative that there is an association between the occurrence of the given species and the occurrence of at least one of the other species. Chi-square for goodness of fit tests the null hypothesis ($H^o{}_2$) that there is no difference between the ratio of the total number of mutual occurrences of a given species with any one of the other species to the number of ponds out of the 32 where the two species do not mutually occur and the ratio of the total number of occurrences of that given species to the number of ponds out of 32 where that species does not occur, against the alternative that there is a difference between these ratios.

Using the five per cent level of significance for the rejection criterion and the one per cent level of significance for indicating high significance the interpretation is as follows:

(a) Chi-square for independence; $H^o{}_1$ is rejected for both pooled and total chi-square values for all taxa and the alternative of a highly significant association between the occurrence of each taxon and the occurrence of at least one or more of the other species is accepted.

(b) Chi-square for goodness of fit; Ilyocypris bradyi; H^o_2 is rejected for Candona spp., Cyclocypris ovum, and Notodromas monacha and is accepted for Potamocypris smaragdina, Cypridopsis vidua and Cyclocypris serena. Thus, I. bradyi is statistically associated with P. smaragdina, C. vidua and C. serena.

Potamocypris smaragdina; H^o_2 is rejected for Candona spp., Cyclocypris ovum, Notodromas monacha and Ilyocypris bradyi and is accepted for Cypridopsis vidua and Cyclocypris serena. Thus, P. smaragdina is statistically associated with C. vidua and C. serena.

Cypridopsis vidua; H^o_2 is rejected for all other species in the succession. However, Cyclocypris serena shows only a significant difference between the ratios (see H^o_2 above) while the others show a highly significant difference indicating that C. vidua and C. serena are associated more often than C. vidua is with any other species.

Cyclocypris serena; H^o_2 is rejected for all species except Cypridopsis vidua for which it is accepted. Thus, C. serena is statistically associated with C. vidua.

Candona spp.; H^o_2 is rejected for Notodromas monacha, Ilyocypris bradyi and Potamocypris smaragdina and is accepted for Cyclocypris ovum, Cypridopsis vidua and Cyclocypris serena. Thus, Candona spp. are statistically associated with C. ovum, C. serena, and C. vidua.

Cyclocypris ovum; H^o_2 is rejected for Notodromas monacha, Ilyocypris bradyi, Potamocypris smaragdina, and Candona spp. and is accepted for Cypridopsis vidua and Cyclocypris serena. Thus, C. ovum is statistically associated with C. vidua and C. serena.

Notodromas monacha; H^o_2 is rejected for Ilyocypris bradyi and Potamocypris

smaragdina and is accepted for the remainder of the species. Thus, *N. monacha* is statistically associated with *C. vidua*, *C. serena*, *Candona* spp., and *C. ovum*.

If the species are listed in order of the proposed succession and the associations among the species are indicated the overall validity of the assumed succession becomes evident.

Species not associated

Succession

Ilyocypris bradyi
Potamocypris smaragdina
Cypridopsis vidua
Cyclocypris serena
Candona spp.
Cyclocypris ovum
Notodromas monacha

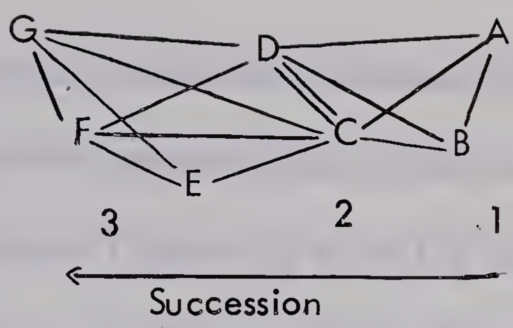
Associated species

The pioneer species, *Ilyocypris bradyi* and *Potamocypris smaragdina*, are not statistically associated with the later species of the succession, *Candona* spp., *Cyclocypris ovum* and *Notodromas monacha*. The two dominant species of the ostracode community, *Cypridopsis vidua* and *Cyclocypris serena*, which characterize the central seral stages of the succession are associated with both groups. The association between *C. vidua* and *C. serena* might be considered as highly significant as they have 29 out of a possible 32 mutual occurrences and the chi-square tests make their association evident.

Alternatively, the results may be shown by using a single line to indicate a significant association and a double line to indicate a highly significant association in the following diagram:

Key:

A- I. bradyi
B - P. smaragdina
C- C. vidua
D- C. serena
E- Candona spp.
F- C. ovum
G- N. monacha



It is clear that two association groups may be defined statistically, the I. bradyi-P. smaragdina-C. vidua-C. serena group and the C. vidua-C. serena-Candona spp.-C. ovum-N. monacha group. Further, although successional direction is not indicated by the components of the groups, a definite order among the three obvious sub-groups is observable.

The faunal succession is supported by demonstrated changes with increasing pond age in much of the environmental data. The linkage between these two inter-related aspects of this ecological succession is based upon the reliability of ostracodes as ecological indicators.

Shoreline erosion and sedimentation continues throughout the history of the borrow-pit pond, but because initially the pits have steeply excavated sides (Figure 7D) shoreline erosion is more pronounced during the first six to eight years. As a consequence, sedimentation is not uniform, through time, either in terms of rate or materials. The prevalence of coarse-textured inorganic sediments that rapidly accumulate an organic component (Figure 9) in the younger ponds and the predominance of finer textured sediments that gradually accumulate an organic component in older ponds illustrate the changes that occur in rates of erosion and sedimentation. Most other physico-chemical properties of the ecosystem are affected by the stabilization of the shoreline, since the main source of the substances controlling these properties is edaphic.

Along with the reduced supply of edaphic substances, increased utilization by the developing community would decrease the concentrations of calcium carbonate, phosphorus and potassium in the bottom sediments (Figure 10) as well as the chlorides, sulfates and total inorganic solids in the pond waters (Figures 13A, 13B and 12B). Hardness, which is normally caused by sulfate, chloride, nitrate, or bicarbonate compounds of iron, calcium, or magnesium, decreases as a result of the diminishing amounts of these chemical substances. It is interesting to note that iron showed no significant change with pond age (Figure 12A) so that the changes in hardness (Figure 13C) are due to changes in the availability of the other substances. Alkalinity, expressed in parts per million of specific calcium carbonate alkalinity (Figure 12B) is mainly due to the presence of bicarbonates.

As the process of community change increases the primary production within the ecosystem, autochthonous organic sediments (Figure 8) increase. Appendix G shows the aquatic plant species that would account for some of the primary production within the ecosystem. Associated with this increase in the importance of the role of primary producers are increases in oxygen saturation (Figure 12C) and in seasonal variations of alkalinity, hardness, total solids, ignition loss and oxygen saturation (Figure 14A - D; Figure 15A - B).

Hydrogen ion concentration (Figure 12D; Figure 14C) which is affected by community respiration, decomposition products of organic detritus, photosynthesis, and other chemical changes (Klugh, 1927) within the ecosystem reflects the total successional changes in the abiotic and biotic components dealt with above. Thus, increase in seasonal variation and decrease in mean pH with age register the sum of the interactions between the components of the borrow-pit pond ecosystem.

3. The effects of physiography and morphometry on the succession in borrow-pit ponds.

The question of whether or not the chronological series of borrow-pit ponds is composed of ponds uniform enough, in terms of gross attributes, to be used to simulate actual changes that would characterize any one of them through time will be answered by a consideration of the physiographic and morphometric factors.

Caution was exercised previously when suggesting that it was unwise to consider the Notodromas monacha stage as representing a climax in the ostracode succession. Before dealing with the effects of physiography and morphometry it is of value to qualify the word 'climax' and determine its significance in this investigation. Two types of climaxes are possible - edaphic and climatic. Climatic climax is normally considered to be a "theoretical community toward which all successional development in a given region is tending.....where physical conditions of the substrate are not so extreme as to modify the effects of the prevailing regional climate" (Odum, 1959). Where physical conditions of the substrate, such as topography, soils and water, modify the regional climate an edaphic climax is usually developed.

On the basis of the above definitions the type of climax that would be ultimately reached in the ostracode succession would be edaphic. Plant succession in the same habitats might end in a climatic climax. The insulating effect of the pond waters and the low variability in climate (Table I) throughout the study area would combine to make the effect of climate fairly uniform. Certainly, topography, geology, soils and vegetation at the pond localities would have a more profound effect upon successional development during the short time interval that is represented by the pond series.

The sorting-out of the individual effects of these edaphic factors is a problem beyond the scope of this study as it would require a detailed knowledge of each pond locality in terms of each factor. However, some useful generalizations might be made that might elucidate their total effect within and between sampling districts.

The three phytogeographic regions (Figure 5) are thought to represent three different climatic climaxes within the area (Moss, 1955) and hence would be controlled by climate. Climate and vegetation, in turn, along with the type of geologic substratum (Figure 3) affect the type of soil developed (Figure 4). Topography, closely allied with the geology of the area, also affects climate, vegetation and hence soil development locally.

Thus, the character of the soils is the most important single factor but the type of geological substratum would also be an important consideration, since both represent the ultimate source of the pond nutrients and hence determine the rate of succession and the type of climax toward which the succession is tending. Fertilizer recommendations in the Alberta Farm Guide (1963) indicate that the Black, Dark Grey and Dark Grey Wooded soils have similar chemical properties in terms of nitrogen, phosphorus, potassium and sulfur. In view of this, ponds in the Eastern district, those in the southern part of the Central district and in the northern part of the Western district (Figure 4) would have equivalent reserves of these chemicals. The Grey Wooded soils predominating in the northern part of the Central and the southern part of the Western districts are reported to be deficient in nitrogen and one or all of the other elements. However, since the sub-soil substrate is an additional source of these nutrients and they are carried into the

ecosystem by surface waters, the differences due to these deficiencies would be minimized. The southern part of the Western district has a yearly mean total of 20.31 inches of precipitation compared with 15.76 inches in the Eastern district (Table I) that would help to offset the lower concentrations of nutrients by more extensive leaching of the pond vicinity. While the foregoing discussion on the interaction of the different physiographic attributes within the sampling districts is admittedly incomplete and general, it serves to illustrate gross similarities in overall effects upon the borrow-pit pond ecosystems.

The uniformity of the borrow-pit pond habitat is further shown by the morphometric data (Table II; Figure 7). The data may be compared statistically by designating two classes arbitrarily, pre-1957 ponds (Class 1) and ponds constructed during 1957 and later (Class 2). Thus, Class 1 ponds would include some ponds located in the Central district along with those of the Western district, while Class II ponds would include the remainder of the Central district ponds and those of the Eastern district. Shore development and the $^{Z}/Zm$ ratio were chosen for making the comparison because they reflect more of the morphometric data than any other parameters. Appendix H is the statistical comparisons of the variability (F-test) and the means (Unpaired t-test) between the two classes for each population*.

When testing the null hypothesis of no difference between the population means against an alternative of a significant difference, it is assumed that the populations are normally distributed and have a common variance. However, by doing an F-test prior to the t-test the latter part of this assumption concerning common

* Population in the statistical sense consists of all values of the variables, shore development and $^{Z}/Zm$, within each class (Steel & Torrie 1960).

variance is tested, (Steel and Torrie, 1960, p. 72ff). The five per cent level of significance was used to choose the rejection region for both tests.

The tests indicate that there is no difference between the two classes in terms of variability or means for either of the two parameters tested. Hence, the effect of morphometry may be considered constant throughout the chronological series of borrow-pit ponds.

4. The ostracode succession and its ecological and paleoecological significance.

Figures 12 to 22 show the over-all and the optimal ranges of 14 abiotic parameters for the successional species of the borrow-pit ponds. Over-all ranges are based upon data gathered at the time live specimens were collected and reflect both seasonal and inter-pond variation. Optimal ranges include only those data gathered during times of peak abundances. The peak abundance for each species was arbitrarily determined by selecting the three most prolific samples.

Some extensions of previously published tolerance ranges are notable. A comparison of the data shown in Figures 19 to 22 with those published by Delorme (1964) indicates that the water temperature, and hydrogen ion concentrations as well as the sulfate, chloride and iron concentration ranges extend the tolerance ranges of at least one of the seven taxa listed.

Since the optimal ranges were determined under the logical assumption that a given species will be most abundant where conditions are optimal for that species, the value of such ranges depends upon the feasibility of quantitative studies. Normally, in studies of Recent communities there is no real problem involved in estimating the size of any given species population. Once these estimations are made a reliable indication of the environmental conditions may be obtained on the basis

Figure 19. Physico-chemical conditions of the bottom sediments at maximum abundance of the successional ostracode species.

Chemical factors considered:

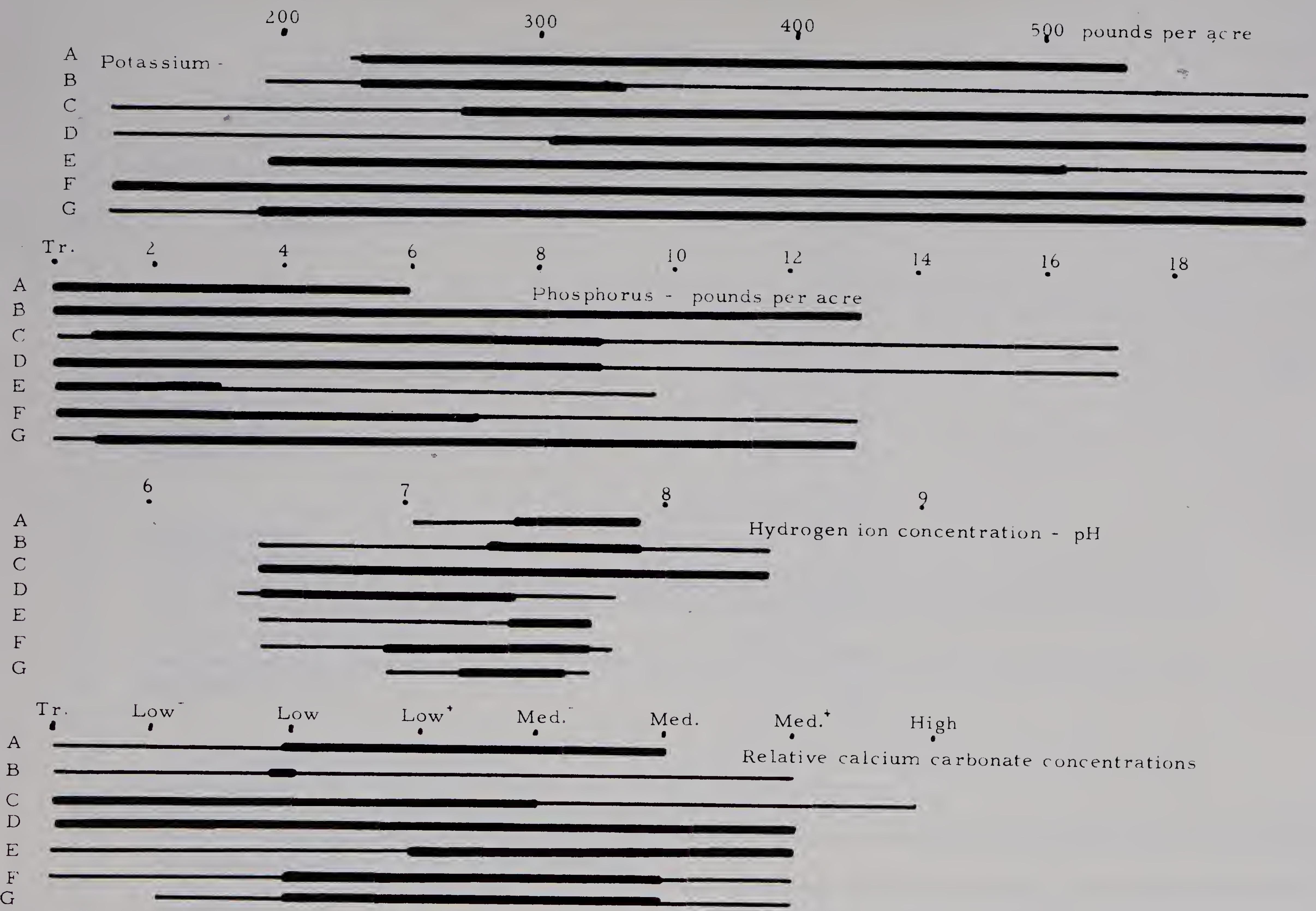
Potassium (pounds per acre)
Phosphorus (pounds per acre)
Calcium carbonate (relative concentrations)
Hydrogen ion concentration (pH)

Key to the ostracode succession for Figures 19 to 22:

A. *Ilyocypris bradyi*
B. *Potamocypris smaragdina*
C. *Cypridopsis vidua*
D. *Cyclocypris serena*
E. *Candona spp.*
F. *Cyclocypris ovum*
G. *Notodromas monacha*

Key to chemical range indicators for Figures 19 to 22:

Over-all range based on occurrence - ———
Optimal range based on maximum abundance - ▬▬▬

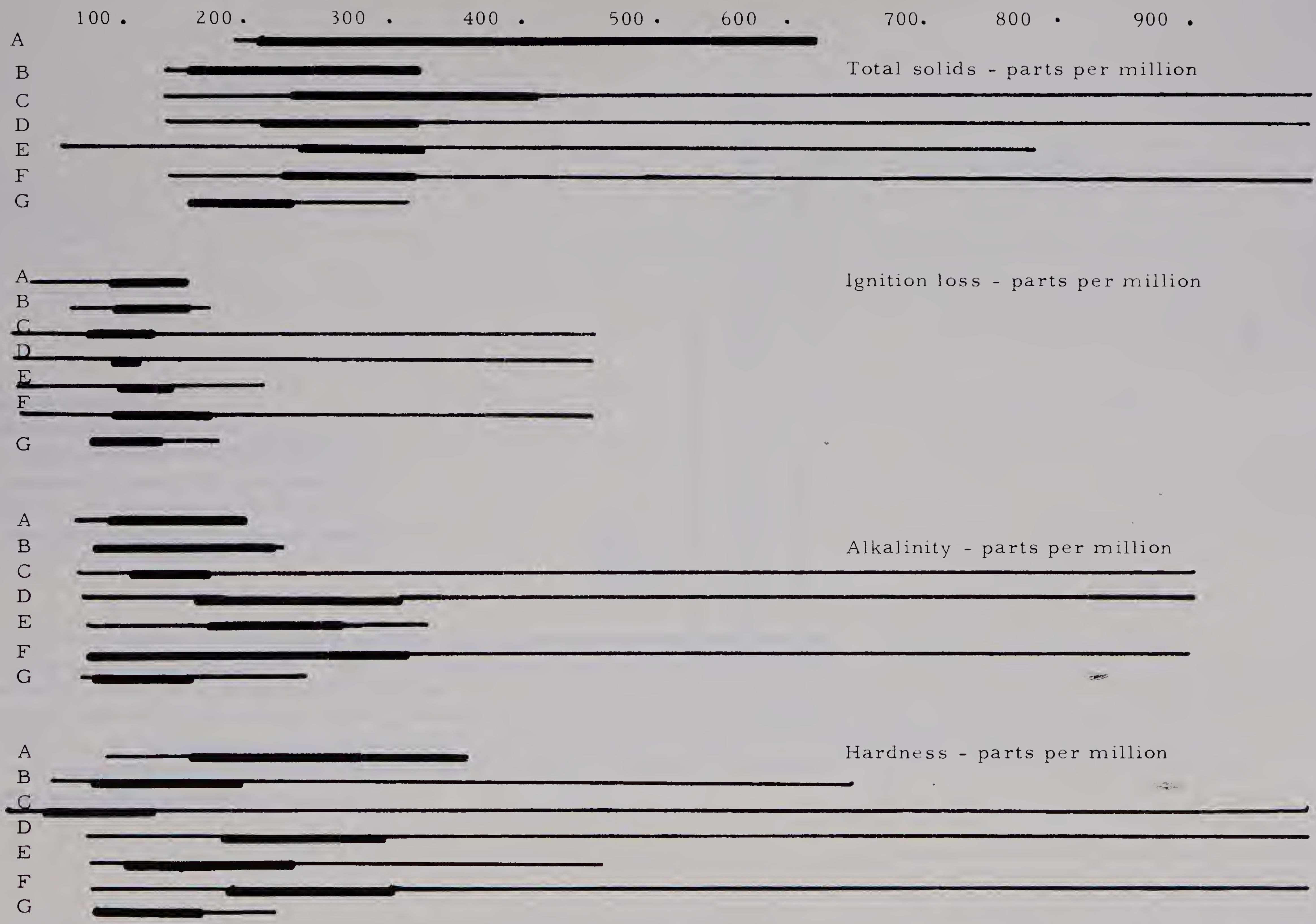


200
300
400
500 pounds per acre
Potassium -
A
B
C
D
E
F
G
Tr.
2
4
6
8
10
12
14
16
18
Phosphorus - pounds per acre
A
B
C
D
E
F
G
6
7
8
9
Hydrogen ion concentration - pH
A
B
C
D
E
F
G
Tr.
Low-
Low
Low+
Med.-
Med.
Med.+
High
Relative calcium carbonate concentrations
A
B
C
D
E
F
G

Figure 20. Physico-chemical conditions of the pond waters at maximum abundance of the successional ostracode species.

Physico-chemical factors considered:

Total solids
Ignition loss
Alkalinity
Hardness



100 . 200 . 300 . 400 . 500 . 600 . 700. 800 . 900 .
Total solids - parts per million
Ignition loss - parts per million
Alkalinity - parts per million
Hardness - parts per million
A
B
C
D
E
F
G

Figure 21. Physico-chemical conditions of the pond waters at maximum abundance of the successional ostracode species. Physico-chemical factors considered:

Iron
Chlorides
Sulfates

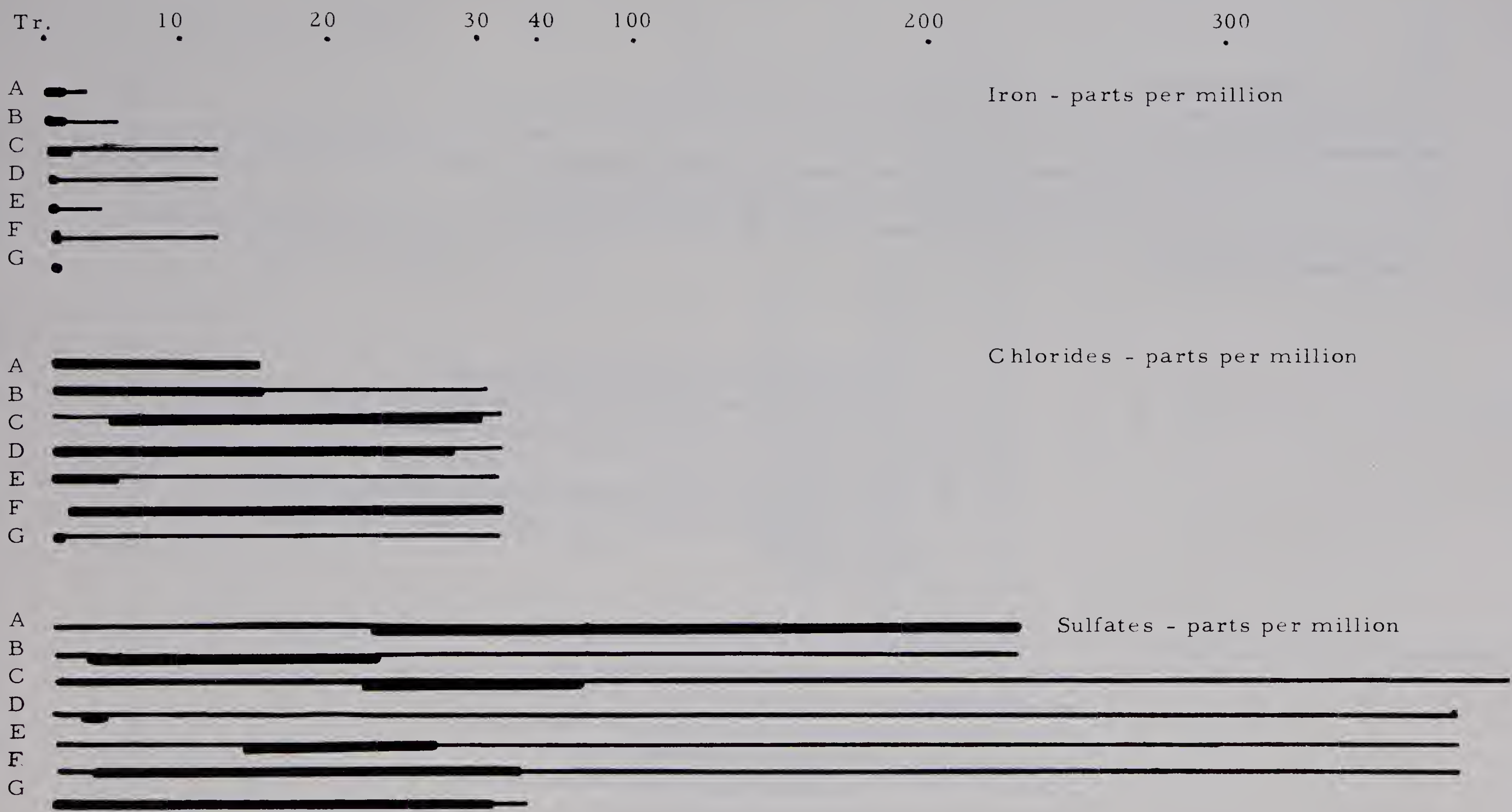
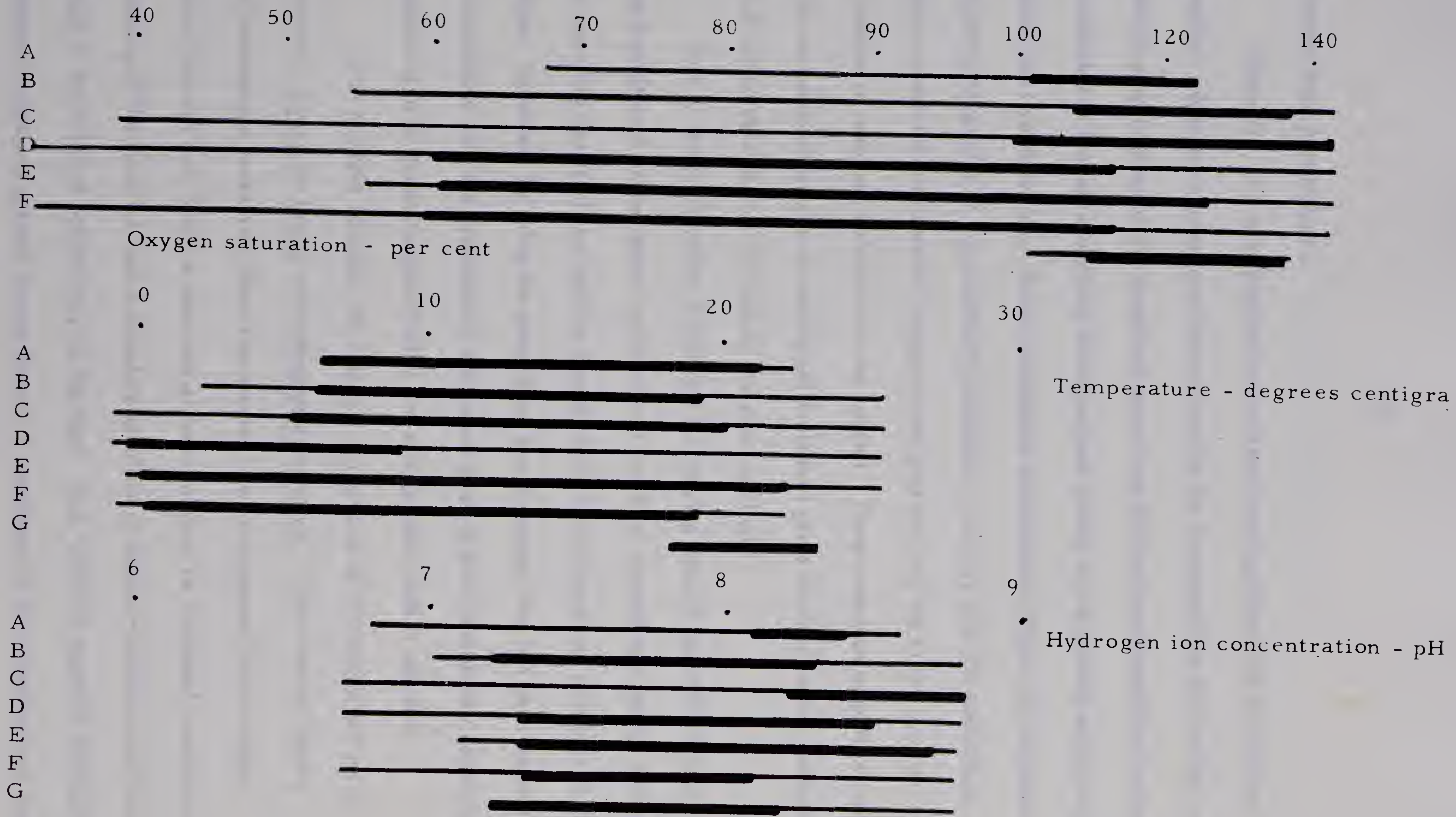

Tr.
10
20
30
40
100
200
300
A
B
C
D
E
F
G
Iron - parts per million
A
B
C
D
E
F
G
Chlorides - parts per million
A
B
C
D
E
F
G
Sulfates - parts per million

Figure 22. Physico-chemical conditions of the pond waters at maximum abundance of the successional ostracode species. Physico-chemical factors considered:

Oxygen saturation
Temperature
Hydrogen ion concentration


40
50
60
70
80
90
100
120
140
A
B
C
D
E
F
Oxygen saturation - per cent
0
10
20
30
A
B
C
D
E
F
G
Temperature - degrees centigra
6
7
8
9
A
B
C
D
E
F
G
Hydrogen ion concentration - pH

of one or more populations.

Naturally, the more populations used the more accurate will be the interpretation. With the successional data available the interpretation will not be confined to an estimation of the conditions prevailing at the time of sampling, but may be extended to include something about the past history of the habitat solely on the basis of the live materials. Since the seasonal distributions (Figure 17) of each of the dominant species of the community are known, not only will the assemblage indicate overall environmental changes in the past but will aid in the reconstruction of changes in seasonal variability in the habitat. These combined aspects of the use of the successional species as ecological indicators gives the fresh-water ecologist a tool comparable to that utilized by the plant ecologist.

Due to the preservation factor and the varying rates of sedimentation in some depositional environments the sub-fossil and fossil assemblages do not give a very accurate record of the relative abundance or the successional positions of the species. However, by using the association group concept that has been shown to be in accordance with the successional data when dealing with Quaternary deposits, the dependence upon accurate quantitative and stratigraphic data is reduced.

As an example consider the first and last species of the borrow-pit pond succession, *Ilyocypris bradyi* and *Notodromas monacha*. If one were to find a fossil assemblage containing these two species in what appeared to be a single horizon then not only might a slow rate of sedimentation be indicated, assuming no reworking of the material, but a complete spectrum of physico-chemical and faunal change in the original habitat may be assumed. And, with the seasonal distributions, tolerance ranges and optimal ranges known, a great deal of the paleoecology would

be available for reconstruction in a logical and orderly manner.

In summary, the ostracode succession as outlined in this thesis might be considered as a meager beginning in the development of a useful vehicle from which much ecological and paleoecological information may be deduced. Further, the ultimate value of using the ostracode assemblage as a universal vehicle is contingent on the expansion of successional studies to include the dominant species from other lentic and the lotic fresh-water habitats.

VIII. CONCLUSIONS

The ostracode community of the borrow-pit pond habitat of Central Alberta is composed of at least thirteen cosmopolitan species: *Cypris pubera*, *Cyprinotus incongruens*, *Cypridopsis vidua*, *Potamocypris smaragdina*, *Cyclocypris ovum*, *Cyclocypris serena*, *Candona candida*, *Candona albicans*, *Candona rostrata*, *Candona suburbana*, *Candona crogmaniana*, *Ilyocypris bradyi* and *Notodromas monacha*.

The borrow-pit ponds, being a relatively uniform biotope and being of datable origin, provide a suitable habitat for studying succession with respect to both physico-chemical and faunal changes.

Six dominant species and *Candona spp.* may be used as indicators to define the seral stages represented in a chronological series of borrow-pit ponds from one to seventeen years old. The resulting ostracode succession, evident from a consideration of each of the seven taxa with regard to: (1) maximum frequency of occurrence for four pond age classes; (2) position of peak abundance within the chronological pond series and (3) statistically demonstrated associations with other species of the proposed ostracode succession, includes: *I. bradyi*, *P. smaragdina*, *C. vidua*, *C. serena*, *Candona spp.*, *C. ovum* and *N. monacha*, from the pioneer stage to the last seral stage represented.

Of the environmental data gathered, successional changes are apparent in the July-October means of most physico-chemical factors and the seasonal variations in these factors.

Because of the restricted habitat the over-all ranges defined are of limited value, however the optimal ranges suggested for the successional species should prove useful in future ecological and paleoecological studies of other pond biotopes at least.

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X. APPENDICES

A. FIELD DATA FORM.

B. BORROW-PIT POND LOCATIONS AND ELEVATIONS.

C. SOIL CLASSIFICATION AND PARENT MATERIAL FOR SAMPLED LOCALITIES.

D. BOTTOM SEDIMENTS ANALYSIS REPORT.

E. POND WATERS JULY-OCTOBER MEANS FOR SELECTED PHYSICO-CHEMICAL DATA.

F. A SIMPLIFIED KEY TO THE BORROW-PIT POND OSTRACODE SPECIES.

G. POND-AGE DISTRIBUTION OF AQUATIC PLANTS.

H. UNPAIRED T-TESTS AND F-TESTS FOR SOME MORPHOMETRIC DATA.

I. CHI-SQUARE FOR INDEPENDENCE AND GOODNESS OF FIT TESTS FOR OCCURRENCES OF THE SUCCESSIONAL OSTRACODE SPECIES.

APPENDIX A

FIELD DATA FORM

1965-66 Field Data

Date.............................   Time......................

Location..........................   Altitude..................

Sample Number...................

Air Temperature...................   Exposure..................

Water Temperature...............(Mean)............

Wind Direction and Intensity.........................

pH (Surface).........................

Secchi disc..........................   Color......................

Samples: Plankton - Volume of H_2O Sampled

- Depth of Samples

Bottom - Weight

- Volume

Substrate: - Color.................Microzone.....................

- Geological Fm. or Mbr..................................

- Soil belt...

Age of Pit.................................Trophic appearance..........

Morphometrics: - Dimensions...

- Depths...

APPENDIX B

BORROW-PIT POND LOCATIONS AND ELEVATIONS

Pond	Borrow Pit Pond Sample numbers	¼	Sec	Tp	Rg	M	Elevation (Feet)	Pond	Borrow Pit Pond Sample numbers	¼	Sec	Tp	Rg	M	Elevation (Feet)	(Year)
(1)	PJ-65-79-57	SE	14	69	1	5	2200	(2)	PJ-65-80-58	SE	14	69	1	5	2200	48
(3)	PJ-65-82-60	SE	14	68	1	5	2200	(4)	PJ-65-84-62	SE	33	67	1	5	2100	
(5)	PJ-65-67-53	NW	32	59	25	4	2200	(6)	PJ-65-68-54	SE	6	60	25	4	2200	52
* (7)	PJ-65-17-17	SW	19	64	20	5	2600		PJ-65-18-18	NW	36	64	21	5	2500	53
	PJ-65-19-19	NE	15	65	21	5	2400	* (8)	PJ-65-20-20	SW	20	66	21	5	2300	
	PJ-65-07-07	SE	32	61	17	5	-	* (9)	PJ-65-12-12	NW	16	63	20	5	2600	54
	PJ-65-13-13	SW	28	63	20	5	2500		PJ-65-14-14	SE	32	63	20	5	2500	
	PJ-65-15-15	SW	5	64	20	5	2500	* (10)	PJ-65-16-16	NE	7	64	20	5	2500	
* (11)	PJ-65-08-08	SW	28	62	19	5	2700		PJ-65-09-09	NE	36	62	20	5	2700	55
* (12)	PJ-65-10-10	NW	2	63	20	5	2600		PJ-65-11-11	NE	10	63	20	5	2600	
(13)	PJ-65-47-47	NW	1	75	21	5	1900	(14)	PJ-65-48-48	SW	12	75	21	5	1900	56
	PJ-65-49-49	SW	13	75	21	5	1900		PJ-65-50-50	NE	23	75	21	5	1900	
* (15)	PJ-65-28-28	NW	9	60	26	4	2200		PJ-65-29-29	SW	16	60	26	4	2200	57
* (16)	PJ-65-30-30	NE	17	61	26	4	2100	(17)	PJ-65-31-31	NW	21	61	26	4	2100	
* (18)	PJ-65-32-32	NW	19	62	26	4	2100	* (19)	PJ-65-33-33	NW	14	64	1	5	2000	58
	PJ-65-34-34	NE	17	62	26	4	2100		PJ-65-35-35	NE	35	62	27	4	2100	
	PJ-65-36-36	NE	16	64	1	5	2000		PJ-65-37-37	SE	32	64	1	5	2000	59
* (20)	PJ-65-38-38	NE	8	65	1	5	2100	* (21)	PJ-65-39-39	NE	17	65	1	5	2100	
	PJ-65-43-43	NW	11	60	25	4	2100		PJ-65-44-44	NE	14	60	25	4	2100	60
* (23)	PJ-65-45-45	SE	23	60	25	4	2100	* (22)	PJ-65-46-46	NW	2	60	25	4	2100	
	PJ-65-04-04	NW	11	56	20	4	2000	* (24)	PJ-65-40-40	SW	9	66	1	5	2200	61
	PJ-65-41-41	NW	16	66	1	5	2200	* (25)	PJ-65-42-42	NW	33	66	1	5	2200	
* (26)	PJ-65-05-05	NE	36	56	20	4	2000	* (27)	PJ-65-22-22	SW	6	57	19	4	2000	62
	PJ-65-23-23	NW	31	56	19	4	2000	* (28)	PJ-65-06-06	NE	36	56	19	4	2000	
	PJ-65-81-59	NE	2	69	1	5	2200	(29)	PJ-65-83-61	SE	33	67	1	5	2100	
	PJ-65-24-24	SW	4	57	19	4	2000	* (30)	PJ-65-25-25	SE	2	57	18	4	2100	63
	PJ-65-26-26	NE	34	56	17	4	2100		PJ-65-27-27	SW	1	57	17	4	2100	
(31)	PJ-65-55-51	SW	4	57	16	4	2100	(32)	PJ-65-56-52	NW	34	56	16	4	2100	64

Pond numbers (1) to (32) - ponds selected for successional study.

* - ponds selected for seasonal study.

APPENDIX C

SOIL CLASSIFICATION AND PARENT MATERIAL FOR SAMPLED LOCALITIES

* (Pond # see Append. B) Sample No.	Soil Zone	*Type	*Description	*Origin (Materials developed on)
57, 58 60, 62	Grey Wooded		Silty clay loam	Till plus ice-contact stratified drift and loess.
53, 54	Black		Silty Loam	Stratified drift - fluvial lacustrine.
17, 18 19, 20	Grey Wooded		Silty clay (17, 20)	Stratified drift - fluvial lacustrine.
07, 12 13, 14 15, 16	Grey Wooded		Silty loam (12, 16)	Till plus ice-contact stratified drift and loess.
08, 09 10, 11	Grey Wooded		Silty loam (08, 10)	Till plus ice-contact stratified drift and loess.
47, 48 49, 50	Grey Wooded		Sandy silt (47, 48)	Stratified drift - fluvial lacustrine.
28, 29 30, 31	Black		Silty loam (28, 30, 31)	Stratified drift - fluvial lacustrine.
32, 33 34, 35	Black		Silty loam (33, 32)	Stratified drift -fluvial lacustrine.

Pond #	Soil Zone	Soil Type	Description	Origin (Material developed on)
36, 37 38, 39	Grey Wooded		Sandy loam (38, 39)	Till plus ice-contact stratified drift and loess.
43, 44 45, 46	Black		Silty Loam (45, 46)	Stratified drift-fluvial lacustrine.
40, 41, 42	Grey Wooded			
04	Black	Chernozemic	Fine Sandy Loam	Alluvial aeolian.
05, 06 22, 23	Black	Chernozemic	Silty Clay Loam	Lacustrine and glacial till.
59, 61	Grey Wooded			
24, 25 26, 27	Black	Chernozemic	Silty Clay Loam	Alluvial lacustrine and glacial till.
51, 52	Black	Solonetzic	Loam	Glacial till.

* The Borrow-Pit pond #'s are grouped according to year of excavation; see Appendix B for complete designation and year.

Where no official data are available the soil type is not given and the description and origin are taken from field observations given in Figure 8 and from the geological map given in Figure 3, respectively.

APPENDIX D

BOTTOM SEDIMENTS ANALYSIS REPORT OF AGRICULTURAL SOIL AND FEED TESTING LABORATORY, UNIVERSITY OF ALBERTA, EDMONTON

Sample Number (See App. B)	Nitrogen	Phosphorous Pounds per acre	Potassium	pH	SO_4 lbs./ac.	$CaCO_3$ (rel.)
25-25	nil	1	230	7.9	nil	low
26-26	nil	nil	362	7.6	500	v.high
27-27	nil	8	342	7.7	nil	low
28-28	nil	9	324	6.4	nil	nil
29-29	nil	nil	476	7.5	nil	low
30-30	nil	9	460	7.7	nil	low
31-31	nil	3	420	7.5	nil	low
32-32	nil	13	332	7.4	nil	low
59-12	nil	7	304	6.9	nil	v.low
60-16	nil	nil	354	7.4	nil	med
61-17	nil	1	360	7.2	nil	low
62-20	nil	6	600-	6.8	nil	trace
52-22-ZM	nil	nil	600-	7.4	nil	med
52-22-2'	nil	4	388	7.5	nil	low
54-25	nil	nil	306	7.7	nil	low
71-28	nil	6	412	7.1	nil	nil
1-1	trace	5	344	8.5	nil	high
4-4	nil	nil	448	7.3	800-	high
5-5	nil	nil	448	7.7	150	med
5-5B	nil	1	296	7.9	nil	high
6-6	nil	2	408	7.8	nil	med
7-7	nil	nil	516	7.4	nil	low
8-8	nil	2	356	7.4	nil	low
9-9	nil	nil	318	7.2	nil	nil
10-10	nil	nil	448	7.2	nil	trace
11-11	nil	nil	398	7.4	nil	med
12-12	nil	nil	600-	7.2	nil	med
13-13	nil	3	594	7.0	nil	nil
14-14	nil	3	368	7.5	nil	low
15-15	nil	nil	416	7.5	100	med
16-16	nil	0.5	504	7.4	trace	med
17-17	nil	2	600-	7.3	nil	med
18-18	nil	nil	360	7.6	nil	med

Sample Number (See App. B)	Nitrogen	Phosphorous Pounds per acre	Potassium	pH	SO_4 lbs./ac.	$CaCO_3$ (rel.)
19-19	nil	0.5	386	7.4	nil	med
20-20	nil	3	600-	7.0	nil	trace
21-21	nil	3	304	6.7	nil	nil
22-22	nil	1	484	7.6	nil	low
23-23	nil	14	372	7.8	nil	low
24-24	nil	22	372	7.6	nil	trace
33-33	nil	9	328	7.3	nil	low
34-34	nil	1	388	7.5	nil	low
35-35	nil	16	412	7.1	nil	trace
36-36	nil	10	344	7.3	nil	low
37-37	nil	7	398	7.2	nil	trace
38-38	nil	4	380	7.5	nil	trace
39-39	nil	6	412	7.4	nil	low
40-40	nil	4	436	7.0	nil	trace
41-41	nil	19	468	7.2	nil	low
42-42	nil	6	556	7.4	nil	low
43-43	nil	16	294	7.3	nil	low
44-44	nil	59	336	7.1	nil	nil
45-45	nil	2	224	7.8	nil	med
46-46	nil	2	268	8.4	nil	v.low
47-47	nil	1	500	7.6	nil	med
48-48	nil	3	500	7.3	nil	med
49-49	nil	6	600-	7.0	nil	nil
50-50	nil	2	600-	7.3	nil	high
51-5 ZM	trace	nil	500	7.4	nil	low
51-5 2'	nil	6	332	7.4	nil	low
53-6	nil	9	528	7.2	nil	low
57-8	nil	17	274	6.3	nil	nil
58-10	nil	3	600-	7.0	nil	trace
72-30	nil	6	362	7.2	nil	v.low
73-32	nil	1	274	7.3	nil	low
74-33	nil	6	342	7.1	nil	low
75-38	nil	3	352	7.5	nil	low

Sample Number (See App. B)	Nitrogen	Phosphorous Pounds per acre	Potassium	pH	SO_4 lbs./ac	$CaCO_3$ (rel.)
76-39	nil	5	472	7.5	nil	low
77-40	nil	3	460	7.3	nil	low
78-42	2	3	596	7.4	nil	low
66-45	nil	3	324	7.6	nil	med
65-46	nil	9	348	7.3	nil	v. low
63-47	nil	4	528	7.4	nil	low
64-48	nil	nil	476	7.4	nil	med
55-51	nil	17	386	7.8	nil	low
56-52	2	nil	392	7.8	nil	high
67-53	nil	3	192	7.7	nil	low
68-54	nil	3	344	7.7	nil	low
79-57	2	6	130	7.7	nil	low
80-58	nil	4	188	7.6	nil	low
81-59	2	5	374	6.4	nil	nil
82-60	nil	4	306	6.7	nil	nil
83-61	nil	nil	352	7.6	nil	low
84-62	nil	4	218	7.4	nil	v. low

APPENDIX E

JULY-OCTOBER MEANS FOR SELECTED PHYSICO-CHEMICAL DATA OF POND WATERS

Pond Number	1 2 3 4	5 6 7 8	9 10 11 12	13 14 15 16 17	18 19 20 21	22 23 24 25	26 27 28 29	30 31 32
Date of Origin 19-	47-48	52-53	54-55	56-57	58-59	60-61	62	63-64
Total Solids	204	352	188	411	234	323	346	285
Ignition loss	107	124	106	119	107	114	116	93
Inorganic solids	97	228	82	292	127	208	232	193
Hardness	138	122	150	256	158	146	216	118
Sulfates	9	34	105	164	14	43	86	48
Chlorides	0.5	1.2	5.4	4.8	0.6	10	2.4	5
Alkalinity	138	103	81	106	160	158	125	140
Iron	1.2	1.8	1.2	1.0	1.1	1.6	0.8	1.8
pH	7.6	8.3	8.1	8.0	7.9	8.0	8.1	8.2
% Oxygen sat.	102	110	108	101	106	104	107	108
Max. depth	5.5	6.2	5.6	9.4	7.5	9.8	5.7	9.0
Limit of vos.	5.0	3.4	4.6	6.4	3.4	7.2	4.4	5.7

* Total solids, ignition loss, total inorganic solids, hardness, sulfates, chlorides, alkalinity and iron are expressed in parts per million.

* Maximum depth and limit of visibility are expressed in feet.

APPENDIX F

A SIMPLIFIED KEY TO THE BORROW-PIT POND SPECIES

Key to borrow-pit pond Cypridacea based on size, shape, colour, ornamentation, and other carapace features.

1. Carapace smooth to punctate with or without hairs 2

1'. Carapace reticulate with two dorsal sulci, outline roughly quadrate in lateral view, venter concave.................I. bradyi

2(1). Lateral outline roughly circular to oval with ventral margin straight to concave, globose in dorsal view.........................3

2'. Lateral outline roughly reniform to crescent-shaped, ventral margin slightly to strongly concave, compressed in dorsal view.......6

3(2). Maximum length greater than l millimeter.........................4

3'. Maximum length less than l millimeter............................7

4(3). Flattened carinate venter, dark brown to black, eyes prominent..N. monacha

4'. Venter not carinate, semi-translucent to opaque, light in color, eyes not prominent...5

5(4'). Valves with surficial concentric (finger-print-like) ornamentation, anterior definitely more broadly rounded than posterior in lateral view...C. pubera

5'. Valves with no surficial concentric ornamentation, scattered punctae, anterior and posterior margins rounded almost equally in lateral view...C. incongruens

6(2'). Valves hairy, less than l millimeter in length, right valve overlapping left along dorsal margin, four muscle scars in main adductor group, greenish..P. smaragdina

6'. Few hairs on valves, usually greater than l millimeter in length, valve overlap not prominent along dorsal margin, five muscle scars in main adductor group, semi-translucent to creamy coloured......Candona spp.

7(3'). Carapace chestnut brown to amber, speckled, uniform, or variegated with darker brown, semi-translucent, smooth surface with few punctae, maximum width less than 0.5 millimeters..................C. ovum

7'. As above, but maximum width greater than 0.5 millimeters....C. serena

7". Carapace not chestnut brown but with brown, blue-green, or green colouring either dispersed evenly or variegated, opaque to translucent, valves smooth to coarsely punctate, highly variable in size but normally between 0.5 and 0.8 millimeters in length.................C. vidua

* All the above species are illustrated in the Plate section.

APPENDIX G

POND-AGE DISTRIBUTION OF AQUATIC PLANTS

SPECIES	PONDS	1	2	3	4	5	6	7	8	9	11	12	13	14	15	16	18	19	20	21	22	23	24	25	27	28	29
Juncus bufonius																											x
Eleocharus acicularis																				x						x	
Ranunculus circinatus																						x			x	x	
Utricularia minor																					x					x	
Ranunculus sceleratus																	x										
Potomogeton strictifolius											x						x			x			x				
Equisetum pratense									x				x														
Potomogeton natans								x																			
Potomogeton variegatum								x																			
Potomogeton friesii							x		x				x	x							x	x				x	
Ranunculus aquatalis							x																				
Potomogeton vaginatus						x						x								x							
Potomogeton foliosus					x											x				x							
Myriophyllum exalbescens		x				x	x	x					x		x	x	x			x			x	x	x		
Chara sp.		x	x			x		x		x								x	x					x		x	
Potomogeton alpinus				x	x																		x				
Potomogeton gramineus			x																								
Potomogeton pectinatus		x													x												
Potomogeton richardsonii		x																	x								

* No aquatic vegetation was recognized from ponds 10, 17, 26, 30, 31 or 32.

APPENDIX H

UNPAIRED T-TESTS AND F-TEST FOR SOME MORPHOMETRIC DATA

Ratio (x) of mean depth (z) to maximum depth (zm)

Western-Central

Pond	x	(x-m)	$(x-m)^2$
1	.51	.03	.0009
2	.50	.04	.0016
3	.63	.09	.0081
4	.49	.05	.0025
5	.73	.31	.0961
6	.60	.06	.0036
7	.42	.12	.0144
8	.58	.04	.0016
9	.38	.16	.0256
10	.50	.04	.0016
11	.52	.02	.0004
12	.59	.05	.0025
13	.49	.05	.0025
14	.56	.02	.0004
	7.50		.1618

Mean $(m_1) = 0.54$
df = 13

Variance $(s_1^2) = \frac{.1618}{13} = .012$

Central-Eastern

Pond	x	(x-m)	$(x-m)^2$
15	.40	.12	.0144
16	.43	.09	.0081
17	.50	.02	.0004
18	.34	.18	.0324
19	.44	.08	.0064
20	.52	.00	.0000
21	.47	.05	.0025
22	.52	.00	.0000
23	.62	.10	.0100
24	.63	.11	.0121
25	.52	.00	.0000
26	.53	.01	.0001
27	.34	.18	.0324
28	.49	.03	.0009
29	.64	.12	.0144
30	.62	.10	.0100
31	.57	.05	.0025
32	.70	.18	.0324
	9.28		.1790

Mean $(m_2) = 0.52$
df = 17

Variance $(s_2^2) = \frac{.1790}{17} = .011$

F-test:

H^o: $s_1^2 = s_2^2$ or F = 1.

$F = \frac{s_1^2}{s_2^2} = \frac{.012}{.011} = 1.09$; Numerator df = 13, Denominator df = 17.

From table of F values: 1% prob. -F = 3.82, 5% prob. -F = 2.53.
H^o is accepted at the 5% level of significance.

Unpaired t-test:

$t = \frac{d}{s\bar{d}} = \frac{(.54 - .52)}{.037} = 0.541$ $\qquad s_{\bar{d}} = \frac{(.1618 - .1790)32}{30 \quad 252} = .037$

H^o: There is no difference between the means $(m_1 = m_2)$.

From table of t values: 1% prob. -t = 2.75, 5% prob. -t = 2.04.

H^o is accepted at the 5% level of significance.

Shore development (x)

Western-Central

Pond	x	(x-m)	$(x-m)^2$
1	1.29	.05	.0025
2	1.14	.10	.0100
3	1.36	.12	.0144
4	1.24	.00	.0000
5	1.18	.06	.0036
6	1.21	.03	.0009
7	1.53	.29	.0841
8	1.13	.11	.0121
9	1.12	.12	.0144
10	1.33	.09	.0081
11	1.35	.11	.0121
12	1.16	.08	.0064
13	1.18	.06	.0036
14	1.13	.11	.0121
	17.35		.1843

Mean (m) = 1.24

Variance $(s_1^2) = \frac{.1843}{13} = .015$

df = 13

Central-Eastern

Pond	x	(x-m)	$(x-m)^2$
15	1.14	.06	.0036
16	1.18	.02	.0004
17	1.31	.11	.0121
18	1.57	.37	.1369
19	1.28	.08	.0064
20	1.22	.02	.0004
21	1.13	.07	.0049
22	1.13	.07	.0049
23	1.16	.04	.0016
24	1.24	.04	.0016
25	1.22	.02	.0004
26	1.15	.05	.0025
27	1.15	.05	.0025
28	1.17	.03	.0009
29	1.20	.00	.0000
30	1.17	.03	.0009
31	1.12	.08	.0064
32	1.18	.02	.0004
	21.72		.1868

Mean (m) = 1.20

df = 17

Variance $(s_2^2) = \frac{.1868}{17} = .011$

F-test:

$H^o: s_1^2 = s_2^2$ or F=1

$F = \frac{s_1^2}{s_2^2} = \frac{.015}{.011} = 1.36$; Numerator def = 13, Denominator df = 17.

From table of F values: 1% prob. -F = 3.82, 5% prob. -F = 2.53.

H^o is accepted at the 5% level of significance.

Unpaired t-test:

$t = \frac{d}{s_{\bar{d}}} = \frac{1.24 - 1.20}{.04} = 1.0$

$s_{\bar{d}} = \frac{(.1843 - .1868)32}{30 \quad\quad 252} = .04$

H^o: = There is no difference between the means $(m_1 = m_2)$.

From table of t values: 1% prob. -t = 2.75, 5% prob. -t = 2.04.

H^o is accepted at the 5% level of significance.

APPENDIX I

CHI-SQUARE FOR INDEPENDENCE AND GOODNESS OF FIT TESTS FOR OCCURRENCES OF THE SUCCESSIONAL OSTRACODE SPECIES

Table of mutual occurrences (disregarding seasonal distribution).

	A	B	C	D	E	F	G
A	9	6	9	8	4	4	1
B		20	20	18	10	10	4
C			31	29	16	20	9
D				29	16	20	9
E					16	13	5
F						20	8
G							9

Key:

A - _I. bradyi_
B - _P. smaragdina_
C - _C. vidua_
D - _C. serena_
E - _Candona spp._
F - _C. ovum_
G - _N. monacha_

Data and computations.

Ilyocypris bradyi (A) Assumed ratio = 9/23 (Total A present) / (32 - total A present)

Other species	A present	A absent	Totals	Deviations pres.	abs.	Chi square	df
B	6	26	32	3	3	1.39	1
C	9	23	32	0	0	0	1
D	8	24	32	1	1	0.14	1
E	4	28	32	5	5	3.86*	1
F	4	28	32	5	5	3.86*	1
G	1	31	32	8	8	9.89**	1
Totals	32	160	192		Total X^2	19.15**	6
					Pooled X^2	12.47**	1

Potamocypris smaragdina (B) Assumed Ratio = 20/12.

C	20	12	32	0	0	0	1
D	18	14	32	2	2	0.53	1
E	10	22	32	10	10	13.33**	1
F	10	22	32	10	10	13.33**	1
G	4	28	32	16	16	34.13**	1
A	6	26	32	14	14	26.13**	1
Totals	68	124	192		Total X^2	87.35**	6
					Pooled X^2	60.10**	1

Cypridopsis vidua (C) Assumed Ratio = 31/1.

D	29	3	32	2	2	4.13*	1
E	16	16	32	15	15	232.22**	1
F	20	12	32	11	11	124.90**	1
G	9	23	32	22	22	499.61**	1
A	9	23	32	22	22	499.61**	1
B	20	12	32	11	11	124.90**	1
Totals	103	89	192		Total X^2	1485.37**	6
					Pooled X^2	1185.21**	1

Other species	Test species present	Test species absent	Totals	Deviations pres.	Deviations abs.	Chi square	df
Cyclocypris serena (D)			Assumed ratio = 29/3.				
E	16	16	32	13	13	62.1**	1
F	20	12	32	9	9	29.8**	1
G	9	23	32	20	20	147.0**	1
A	8	24	32	21	21	162.2**	1
B	18	14	32	11	11	44.5**	1
C	29	3	32	0	0	0	1
Totals	100	92	192		Total X^2	445.6**	6
					Pooled X^2	335.7**	
Candona spp. (E)			Assumed ratio = 16/16.				
F	13	19	32	3	3	1.12	1
G	5	27	32	11	11	15.12**	1
A	4	28	32	12	12	18.00**	1
B	10	22	32	6	6	4.50*	1
C	16	16	32	0	0	0	1
D	16	16	32	0	0	0	1
Totals	64	128	192		Total X^2	38.74**	6
					Pooled X^2	10.69**	1
Cyclocypris ovum (F)			Assumed ratio = 20/12.				
G	8	24	32	12	12	19.2**	1
A	4	28	32	16	16	34.1**	1
B	10	22	32	10	10	13.3**	1
C	20	12	32	0	0	0	1
D	20	12	32	0	0	0	1
E	13	19	32	7	7	6.55**	1
Totals	75	117	192		Total X^2	73.2**	6
					Pooled X^2	45.0**	1
Notodromas monacha (G)			Assumed ratio = 9/23.				
A	1	31	32	8	8	9.9**	1
B	4	28	32	5	5	3.9*	1
C	9	23	32	0	0	0	1
D	9	23	32	0	0	0	1
E	5	27	32	4	4	2.5	1
F	8	24	32	1	1	0.14	1
Totals	36	156	192		Total X^2	16.44*	6
					Pooled X^2	8.35**	1

Significance levels:
(Steel and Torrie, 1960)

Probability	Value of t	Degree of freedom (df)
5 %	3.84	1
1 %	6.63	1
5%	12.6	6
1%	16.8	6

Rejection region - 5 % probability.

High significance - 1 % probability.

*Statistically significant difference between the assumed ratio and the actual ratio.

**Statistically highly significant difference between the assumed ratio and the actual ratio.